This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

698 1

Becker

SMITHSONIAN MISCELLANEOUS COLLECTIONS.
358

THE

CONSTANTS OF NATURE.

PART IV.

ATOMIC WEIGHT DETERMINATIONS:

A DIGEST

OF THE INVESTIGATIONS PUBLISHED SINCE 1814.

BY

GEORGE F. BECKER.

WASHINGTON:
SMITHSONIAN INSTITUTION.
AUGUST, 1880.

THE NEW YORK
PUBLIC LIBRARY

ASTOR, LENOX AND
TILDEN FOUNDATIONS.
1909

JUDD & DETWEILER, PRINTERS,
WASHINGTON, D. C.

ADVERTISEMENT.

The following forms the *fourth* part of a general work on the "CONSTANTS OF NATURE," of which the first three are as follows:

Part I and Supplement.—Specific Gravities, Boiling Points and Melting Points, by F. W. Clarke.

Part II.—A Table of Specific Heats for Solids and Liquids, by F. W. Clarke.

Part III.—Tables of Expansion by Heat for Solids and Liquids, by F. W. Clarke.

The manuscript of the present work has been presented to the Smithsonian Institution by Mr. G. F. Becker and is published at the expense of its fund.

S. F. BAIRD,
Secretary Smithsonian Institution.

WASHINGTON, AUGUST, 1880.

PREFACE.

Of the fundamental importance of the most accurate attainable knowledge concerning the true atomic weights of the elements there can be no two opinions. If the enormous mass of known facts relating to the properties of matter is ever to be brought under wide generalizations, it is with the simple substances that a beginning must be made, and with the simplest property of these substances, the relative weights of their ultimate particles. Berzelius held this view and the labors of Mendelejeff, Meyer and others leave no question as to the fact of a relation between the atomic weights and the properties of simple and compound matter. Accurate information on the subject, however, is not easily attainable; different writers on chemistry follow different authorities, and some even take a mean between the results arrived at by experimenters of different degrees of skill and accuracy, or assume some convenient number without experimental foundation. Nowhere, to my knowledge, is there even an approximately complete list of the determinations that have been made.

Forced back, myself, upon the original memoirs for information, I believed that I should do other chemists a service in presenting to them a short but systematic digest of each investigation on the subject, including the following points, so far as they could be ascertained: The nature of the material experimented upon, and the method of its preparation; the experimental method adopted to effect the determination, and the number of experiments; the mean result reached by the experiments, and the extreme difference between the results; such a record of the constants employed in the calculation as will enable any one to recalculate the results for different constants; and the place in literature where the original paper is to be found.

The following pages are the result. From the information

he will find in them, the experienced chemist will, in most cases, I think, be able to decide which determination offers the best guarantees for accuracy, or at least between which determinations his choice must lie, forming his judgment to a great extent independently of the comparative reputation of the observers—not always a safe guide where one is, in a general way, the unquestionable superior of the other—and no guide at all when the names carry on the whole an equal weight. As a record of the direction investigations have taken and of analytical methods of the most exact character also, I hope that this digest may not be without value.

As this compilation would serve rather to mislead than to assist investigators, unless it be accurate and practically exhaustive, it seems proper to explain the manner in which it has been prepared. Believing it best to work independently of any previous compilations, I selected as my base the three great German journals—*Poggendorff's Annalen*, *Liebig's Annalen*, and *Erdmann's Journal für Praktische Chemie*. My choice was determined not only by the position these journals take in chemico-physical science, but by the fact that their indices are admirable, and their tone cosmopolitan; all of them, until lately, having furnished their readers with the scientific news of the time, and with abstracts from and translations of the important papers published elsewhere and in whatever language, as well as with original investigations. The indices of these journals I read through from beginning to end, making an extract of every entry which bore on the subject of atomic weights, or which I suspected might do so. In studying the articles thus reached, every reference to other atomic weight determinations was preserved, and the originals, so far as possible, sought out; a task in which the Royal Society's *Catalogue of Scientific Papers* was of the greatest assistance. Having exhausted the supply of information in these journals, I turned to *Berzelius' Jahresbericht*, and to its continuation edited by *Kopp*, *Liebig et al.*, and made a study of their contents by the same method. Later, I made a similar systematic study of the *Annales de Chimie et de Physique*, the *Bericht der Deutschen Chemischen Gesellschaft*, the *Chemical*

News, *Fresenius' Zeitschrift für Analytische Chemie*, the *Journal of the Chemical Society*, the *Proceedings of the Royal Society*, and the *Philosophical Transactions*, and of *Silliman's American Journal of Science*. I have also made some use of the *Philosophical Magazine*, and a great deal of use of the *Paris Comptes Rendus*. These publications are not so indexed as to make their contents readily available; but what appears in the *Comptes Rendus* is pretty sure to be noticed elsewhere, and I scarcely think that any determinations there published have escaped me. I have also made use of the *Bibliothèque Universelle*, *Archives des Sciences* of Geneva, (an incomplete set, unfortunately,) the *Zeitschrift für Berg-Hütten-und Salinen-Wesen im Preussischen Staate*, *Thomson's Annals of Philosophy*, *Gilbert's Annalen der Physik und der Physikalischen Chemie*, the *British Association Reports*, the *Transactions of the Royal Society of Edinburgh*, the *Transactions of the Academies of Brussels* and of *St. Petersburg*, and have consulted numerous works on chemistry, particularly *Berzelius' Lehrbuch der Chemie* and *Gmelin-Kraut's Handbuch der Chemie*.

I have not thought it necessary, or even desirable, to extend my search for atomic weight determinations further back than Wollaston's famous "Table of Equivalents," published in the *Philosophical Transactions* for 1814. It is true that numerous determinations had been made before that time, but, with the exception of those mentioned by Wollaston, few which can be of either interest or value to the chemist of the present day, except from a purely historical point of view. From Wollaston's table onwards, I have not felt that the purposes of this paper permitted of any selection between atomic weight determinations, however valueless many of them might appear to my own judgment. Indeed, it has cost me more labor to put many ill-made and ill-reported investigations into proper form for this digest than was required for a majority of those determinations upon which I set the highest value. In the attempt to make a complete collection of the determinations since the time indicated, a few may have escaped my search; but, if so, they must have fallen singularly dead upon the chemical world, and would be unlikely to repay further labor in seek-

ing them. On the other hand, I have rigidly excluded atomic weights calculated from analyses never designed so to be used. Any chemist, upon whose experiments we could rely, would proceed in a very different manner in making an atomic weight determination, from that which he would select for an ordinary analysis, and to put his credit at stake by calculating atomic weights from analyses not designed for this use is alike unfair to him and to the scientific public, which is asked to receive as an atomic weight determination what really is not such.

The purpose of this paper is distinctly not critical, and the remarks I have added to, or inserted in, the digest are simply explanatory. I have, however, frequently mentioned criticisms which have appeared in literature when they seemed pertinent.

As for the accuracy with which the digests have been made, I may state that the preponderating importance of this point has been constantly before my mind. In the effort to crowd the maximum amount of information into the fewest words, I have had occasion to refer to most of the papers digested a number of times, and at long intervals. I have always taken advantage of such occasions, as well as those on which I have met with a reprint, translation or abstract of a determination, to verify the rough draughts of my digests. Only in a couple of instances have I thus discovered a trifling error. On the other hand, I have been able to detect and point out numerous misprints and miscalculations in the original sources. While, therefore, I cannot hope entirely to have escaped error in the thousands of values I have copied, and the almost equal number of calculations I have made, I have strong hopes that the accuracy of this digest will be found at least on a par with that of the original papers.

When, as is the case with provoking frequency, chemists have given their analytical data, but have omitted to state the atomic weights, or other constants, assumed in calculating their results, I have recalculated their data with accepted constants, which I have in each case stated. I have also, in many instances, recalculated determinations of importance,

in which constants varying considerably from those now received were assumed. I have further reduced the determinations originally given in terms of O = 100, or of O = 15.96, to O = 16. No confusion, however, will be found between the numbers for which the original investigators are responsible and my own. All values which I have calculated are in italics, or, with my explanations, enclosed in square brackets. The only arithmetical operation I have permitted myself to perform without these indications is a multiplication or division by two; and even in such cases it will usually appear from the digest itself that this operation has been performed.

The abbreviations of the literary references are essentially those adopted in the Royal Society's *Catalogue of Scientific Papers*. The first reference in each case is to the source upon which I have depended. When two references are necessary, they are connected by the word *and*. When my authority is not the original source, that to which it is accredited in my authority is also mentioned.

In conclusion, I shall be grateful to any one who, by drawing my attention to omissions or mistakes, will assist me in perfecting a labor which has occupied all my available time for twenty months.

BERKELEY, CAL., *April*, 1878.

POSTSCRIPT.

In preparing the following paper, I designed making it preliminary to a discussion of the various determinations and of the value to be assigned to each, and in this work I had already made some progress. After presenting this paper to the Institution, however, I learned that Prof. F. W. Clarke had been for some time engaged on a similar undertaking, and to him I gladly resigned the discussion of the data here compiled. The two papers will appear in the same form, and may be regarded as complementary.

G. F. B.

ATOMIC WEIGHT DETERMINATIONS.

ALUMINIUM.

The specific heat of aluminium, as determined by Regnault and by Kopp, and the vapor density of volatile compounds, as determined by Deville and Troost and by Odling, indicate that the atomic weight of this element is about 27.5. (*Gmelin-Kraut, Handbuch der Chemie, 1*, 39; and *L. Meyer, Moderne Theorien der Chemie*, 50.)

J. J. BERZELIUS: *27.267* (O = 16).

100 parts of anhydrous aluminic sulphate decomposed by heat, gave 29.934 parts of oxide. Preparation not described. Number of experiments, probably 1. In *Berzelius' Lehrbuch* these data are calculated for S = 200.75, and give Al = 170.9 (O = 100,) or *27.344* (O = 16.) [If S = 32, the data give Al = 27.267.] (*Poggend. Ann., 8*, 1826, 187.*)

T. THOMSON: *30* (O = 16).†

Thomson found, probably from analysis of the sulphate, (see appendix,) that 125 Al = 100 O. Thomson supposed aluminic oxide to be a protoxide. [If it is a sesqui-oxide, the data give Al at 30.] (*Thomson's System of Chemistry*, 7th ed., *1*, 1831, 454.)

W. W. MATHER: 20.55 (O = 16).

According to this chemist 0.646 grammes of chloride, prepared according to Woehler, gave 2.055 grammes argen-

* This article by Berzelius, which contains the particulars of a large part of his earlier atomic weight determinations, will be referred to frequently in the course of this paper. It is unfortunately full of misprints, all of which are, by no means, corrected in the table of errata at the end of the volume. The correctly printed values of the atomic weights discussed in it are to be found in *Poggend. Ann.*, 10, 1827, 339.

† It must be remarked, in justice to Dr. Thomson, that his atomic weight determinations are, properly speaking, of a different nature from those of other chemists. So thoroughly persuaded was he of the truth of Prout's hypothesis, (that the atomic weights of the elements are all exact multiples of that of hydrogen,) that his experiments were directed merely towards ascertaining *which* multiple, in any case, was to be adopted.

tic chloride, and 0.2975 aluminic oxide. (*Silliman's Amer. Journ.*, *27* 1835, 138, 241.) Berzelius points out the inconsistency of these data. (*Berzelius' Jahresbericht*, *15*, 1835, 138.)

C. TISSIER: *27.12* (O = 16).

Determined by dissolving aluminium in chlorhydric acid, evaporating to dryness with excess of nitric acid and decomposing the nitrate by heat. The aluminium employed contained 0.135 per cent. sodium. 1.935 of this metal gave 3.645 oxide. [If Na = 23, these data give Al = 27.12.] The metal was prepared by heating aluminic fluoride with purified sodium in a graphite crucible. (*Paris Comptes Rend.*, *46*, 1858, 1105.)

J. DUMAS: 27.446 (O = 16).

Determined by six experiments on the titration of aluminic chloride with argentic nitrate. The mean result was Al = 13.723 (0=8); extreme difference 0.09. The aluminic chloride, which had been prepared on a large scale, was purified by sublimation over iron-filings and over aluminium filings, and by a third sublimation in a current of hydrogen over aluminium filings, after which it was melted. Experiments on the oxidation of aluminium were found unsatisfactory on account of the difficulty of obtaining the metal pure. They gave Al at from 13.74 to 13.89. Dumas takes Ag = 108; Cl = 35.5. (*Ann. de Chim. et de Phys.*, (3,) *55*, 1859, 151.)

W. ODLING: 27.5 (O = 16).

Determined from the vapor density of aluminium methide and ethide at 220° and upwards. (*Phil. Mag.*, (4,) *29*, 1865, 316.)

—. ISNARD: 27 (O = 16).

Pure aluminium dissolved in chlorhydric acid, evaporated and heated to redness, gives $\frac{17}{9}$ of its weight in oxide. (*Paris Comptes Rend.*, *66*, 1868, 508.)

Pelouze and Fremy give *27.357* (O = 16); 170.98 (O = 100,) for the atomic weight of aluminium, and assert that this value is derived from the composition of potash-alum, but they give no authority for the value. The experiments were made by precipitation with barium chloride. (*Traité de Chimie*, 3d ed., *1*, 50.)

ANTIMONY.

From the specific heat of antimony, as determined by Bunsen, Regnault, and others, and from the vapor density of volatile compounds, as determined by Mitscherlich, Loewig and Schweizer and others, it is certain that the atomic weight must be about 120. (*Gmelin-Kraut*, *l. c.;* and *L. Meyer*, *l. c.*)

J. J. Berzelius: *129.03* (O = 16); 806.452 (O = 100).

100 parts of pure antimony, oxidized with nitric acid, evaporated to dryness, and heated to redness, gave 124.8 antimonic antimoniate. The number of experiments and the preparation of the metal are not given. (*Poggend. Ann.*, *8*, 1826, 23.)

R. Schneider: 120.3 (O = 16); 751.9 (O = 100).

Determined by experiments on the reduction of native antimonic ter-sulphide in a current of hydrogen. The only foreign substance to be found in the mineral was silicic acid, which was determined in each case. The temperature was kept as low as possible, and the amount of sulphide volatilized, and of that undecomposed by the process, was determined. The mean composition, as ascertained by eight experiments, was 71.48 antimony—extreme difference, 0.078; and 28.52 per cent. sulphur. The atomic weight was calculated from the mean for S = 200. (*Poggend. Ann.*, *98*, 1856, 293.) Schneider published a preliminary note in *Poggend. Ann.*, *97*, 1856, 483, in which, from a portion of the above-mentioned experiments, he deduced the value 120.25.

H. Rose and Weber: *120.626* (O = 16).

Rose published this determination expressly as a confirmation of Schneider's value. Antimony ter-chloride was dissolved in water containing tartaric acid, and decomposed by hydrogen sulphide. Sulphur was removed from the filtrate by ferric sulphate, and the chlorine determined with argentic nitrate. 2.162 antimony chloride were found equivalent to 4.097 argentic chloride. [If Ag = 107.93 and Cl = 35.457, these data give Sb = 120.626; or, for O = 100, Sb = 753.92.] Rose, adopting some other values gets 1508.67 [twice 754.34.] He also recalculates some earlier

analyses of the ter-chloride, and the penta-chloride (*Poggend. Ann.*, *3*, 1825, 443) made by himself by the same method, which give respectively 1512.91 and 1508.6. (*Poggend. Ann.*, *98*, 1856, 455.)

W. P. DEXTER: 122.336 (O = 16); 764.6 (O = 100).

Attempts were made to determine the atomic weight of antimony from its reducing action on the chloride of gold, but no constant result was obtained. Berzelius' method (*vide supra*) was, therefore, adopted. From the mean of ten irreproachable experiments Dexter deduces the value 1529.2; extreme difference, 3. The metal was prepared as follows: From antimony tartrate, sodium metantimonate was prepared, and antimonic acid separated out with nitric acid. The antimonic acid was reduced with carbon, and melted with another portion of antimonic acid to remove traces of sodium, etc. It was also heated in a current of hydrogen to remove traces of oxide. The investigation was carried out in Bunsen's laboratory, and with his assistance. (*Poggend. Ann.*, *100*, 1857, 563.)

J. DUMAS: 122 (O = 16).

Neither the reduction of cervantite nor of the sulphide, nor the oxidation of metallic antimony gave accordant results. Dumas, therefore, resorted to the analysis of the ter-chloride with argentic nitrate. The chloride was prepared by three different methods, and was dissolved in water acidulated with tartaric acid. Seven experiments gave an average of 121.975; extreme difference, 0.69. Ag = 108; Cl = 35.5. (*Ann. de Chim. et de Phys.*, (3,) 1859, 175.)

F. KESSLER: 122.24 (O = 16).

In four experiments crystals of antimony ter-oxide were employed. This oxide had been sublimed in a current of pure, dry carbonic acid. A known weight of the compound was nearly oxidized in a chlorhydric acid solution by a known, slightly insufficient, weight of potassic chlorate. The remainder was titrated with a standard solution of potassic bi-chromate, and countertitrated with ferrous chloride. The mean result was Sb = 122.16. In three experiments metallic antimony was employed. It was prepared by reducing the precipitate formed when ammonic hydrate is added to stibium-ammonium tartrate. The metal was oxidized in chlorhydric acid solution by potassic chlorate, (not weighed,) and reduced to antimony ter-chloride by

stannous chloride. The excess of this reagent was chloridized by mercuric chloride, calomel being separated by filtration. The experiment was continued exactly as in the cases where the oxide was taken to start with. The mean of the experiments on metallic antimony was 122.34. The mean of the seven experiments above described is 122.24; extreme difference, 0.94. K = 39.12; Cl = 107.97. Kessler also made experiments by Rose's method, but got discordant results. (*Poggend. Ann.*, *113*, 1861, 145.)

B. Unger: 119.76 (O = 16).

Determined by analysis of sodium sulph-antimonate, (Schlippe's Salt.) (*Kopp's Jarresbericht*, 1871, 325; *Arch. der Pharm.*, (2,) *147*, 193; *148*, 1.) A single determination by a method from which great accuracy could not be expected. S = 32; Na = 23. (J. P. Cooke, Jr., in *Proc. Amer. Acad.*, *13*, 6.)

J. P. Cooke Jr.: 120 (O = 16).

Cooke objects to the determinations of Dexter and Dumas, on the ground that there is no sufficient evidence of the absence of higher or lower compounds of the same elements in the salts employed.

In two experiments antimony was dissolved and precipitated as sulphide, which was heated to 240° before weighing. The formation of free S was prevented, occluded tartaric acid was determined, but occluded oxy-chloride was neglected. The experiments gave each Sb = 120.6 for S = 32. In thirteen experiments Sb was dissolved in a minimum of nitric acid, and the solution boiled over bullets of Sb to complete saturation. The sulphide was then precipitated in an atmosphere of carbon di-oxide. The precipitate contained no free S. The oxy-chloride was driven off at 180° and determined. The tartaric acid was decomposed at 210° and determined. The errors are opposed and minute. The mean of the weighings of sulphide, dried at 180°, gave Sb = 119.994 for S = 32; extreme difference, 1.01. The mean of weighings of sulphide heated to 210° gave Sb = 120.295; extreme difference, 1.07. General mean Sb = 120.145. Fifteen analyses of antimonious bromide gave the Br contents at 66.6665 per cent. for Ag = 108, Br = 80, with an extreme difference of 0.195. This composition gives Sb 120. In seven experiments the iodide was analyzed. For I = 127 and Ag = 108, it gave a mean of 76.051 per cent. Sb, or Sb = 120. It was also shown that the chloride

cannot be prepared free from oxy-chloride, and that its Sb and Cl contents correspond to Sb = 120. Metallic Sb was prepared by reduction of sodic antimoniate, or of oxide, with potassic cyanide, or by Liebig's method. In all cases it was fused for several hours under its own oxide. The haloid salts were purified by fractional recrystallization and distillation, in part in a current of carbon di-oxide. (*Proc. Am. Acad.*, *13*, 1877, 1.)

ARSENIC.

The specific heat of metallic arsenic, as determined by Regnault, and the vapor density of a number of volatile compounds, as determined by Dumas, Mitscherlich, Bunsen, and others, prove that the atomic weight of this element must be in the neighborhood of 75. (*Gmelin-Kraut*, *l. c.*; and *L. Meyer*, *l. c.*)

J. J. Berzelius: 75.1 (O = 16); 469.4 (O = 100).

2.203 grammes of arsenious acid, heated with sulphur in a distilling apparatus in such a manner that sulphurous acid, but no sulphur, could escape, set free 1.069 grammes sulphurous acid. If S = 200.75, the value follows. (*Poggend. Ann.*, *8*, 1826, 22; and *Lehrbuch*, 5 ed., *3*, 1205.)

J. Dumas: *75* (O = 16).

Dumas found the vapor density of arsine 2.695. [This value multiplied by 28.94278 gives As = (sensibly) 75.] (*Ann. de Chim. et de Phys.*, *33*, 1826, 337.)

J. Pelouze: *75* (O = 16); 468.75 (O = 100).

A known weight of arsenic ter-chloride was introduced into a nitric acid solution of a known weight of perfectly pure silver, the chloride being in slight excess. The excess of chloride was then titrated with decimal silver solution.* As the mean of three experiments Pelouze found As = 937.50; extreme difference, 0.8. Ag = 1349.01; Cl = 443.2. The ter-chloride was repeatedly distilled to free it from excess of chlorine. It was colorless, dissolved com-

* This method, which has been frequently employed in the determination of atomic weights, will be referred to as "Pelouze's method."

pletely in chlorine, and boiled between 134° and 135°. (*Paris Comptes Rend.*, *20*, 1845, 1047.)

J. DUMAS: 74.94 (O = 16).

Determined by four experiments on the titration of arsenic ter-chloride with argentic nitrate, the ter-chloride being prepared in several lots. The number is the mean of the experiments; the extreme difference being 0.15. Dumas takes Ag = 108; Cl = 35.5. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 174.)

F. KESSLER: 75.2 (O = 16).

In six experiments arsenious acid was titrated with potassic bichromate and counter-titrated with ferrous chloride. The number so obtained was 75.15. In twelve experiments a known weight of arsenious acid was oxidized in caustic potash solution by potassic chlorate, the arsenious acid being slightly in excess, acidified with chlorhydric acid and the excess of arsenious acid titrated with potassic bichromate and counter-titrated with ferrous chloride. The oxidizing action of the potassic bichromate was experimentally determined. The number obtained from these experiments was 75.24. Five experiments were made with acid instead of alkaline solutions of arsenious acid; they gave 75.15. The arsenious acid was colorless, transparent, volatilized without any residue, and was thoroughly dessicated. Kessler assumed K = 39.12; Cl = 107.97. (*Poggend. Annal.*, *95*, 1855, 210; *113*, 1861, 140.)

BARIUM.

The specific heat of barium compounds, especially of the chloride, as determined by Regnault and by Kopp, shows that the atomic weight of this element lies in the neighborhood of 137. (*Gmelin-Kraut*, *l. c.*)

WOLLASTON and KLAPROTH. *139.2* (O = 16); 870 (O = 100).

Klaproth found that 100 parts of carbon di-oxide were equivalent to 352.57 parts barium oxide, and that 34 parts sulphuric anhydride were equivalent to 66 parts of barium

oxide. If C = 75.4, and S = 200, the value follows. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *136.79* (O = 16).

100 parts of barium chloride gave 138.08 and 138.06 parts argentic chloride. [If Ag = 107.93, and Cl = 35.457, the above value follows.] Berzelius also determined barium from the sulphate; 100 parts barium chloride gave 112.17 and 112.18 parts sulphate. Calculated for S = 200.75 this determination is almost identical with the other; Berzelius, however, expressly adopts the former. [Calculated for S = 32.0742, it gives 135.74.] (*Poggend. Annal.*, *8*, 1826, 189, and *Lehrbuch der Chemie*, 5th ed., *3*, 1229.)

E. TURNER: 137.4 (O = 16).

Turner determined the chlorine contents of barium chloride at 34.016 per cent. by precipitation with silver. This number was the mean of the best two experiments made, and the value follows from it on the assumption that Cl = 35.42. The barium chloride was prepared from native carbonate by solution in chlorhydric acid, precipitation of impurities with barium oxide, ignition of the chloride, treatment with alcohol, and recrystallization. (*Phil. Trans.*, *119*, 1829, 291.*)

T. THOMSON: *136* (O = 16); 850 (O = 100).

Thomson had formerly determined this atomic weight at 875 by mixing potassic sulphate with barium chloride in such proportions that the supernatant liquid contained no sensible amount of either sulphuric acid or barium. Turner having shown the fallacy of this method, Thomson substituted ammonium sulphate, and also sulphuric acid for the potassium salt, and found 9.5006 barium oxide equivalent to 5.00 sulphuric anhydride. He also analyzed the chloride with argentic nitrate, assuming silver = 1375, and chlorine = 450, and reached the same conclusion with reference to barium. (*Thomson's System of Chemistry*, 7th ed., *1*, 1831, 426.)

---

* Turner made the discovery in the course of this investigation that barium sulphate carries down other salts, such as potassic sulphate, which cannot be extracted from the precipitate by any degree of washing, and that determinations, with barium sulphate, are consequently unreliable. Although Berzelius drew attention to the importance of the observation, and Thomson was obliged to acknowledge errors in his work from this cause, the fact was for a long time nearly forgotten, as can readily be proved from the contents of this digest.

—. SALVETAT: 136 (O = 16); 850 (O = 100).

Determined from the loss of weight ensuing on the decomposition of barium carbonate by sulphuric acid. Details not given. (*Paris Comptes Rendus*, *17*, 1843, 318.)

J. PELOUZE: *137.28* (O = 16); 858.01 (O = 100).

Into a nitric acid solution of a known weight of perfectly pure silver, a known and slightly more than equivalent weight of barium chloride was introduced. The excess was titrated with decimal silver solution. The value is the mean result of three experiments, which give an extreme difference of 0.22 for O = 100. The barium chloride was purified by recrystallizations continued till determinations gave a constant result, and was dessicated in part at 200°, and in part at a temperature just below redness. Pelouze took Ag = 1349.01, and Cl = 443.2. (*Paris Comptes Rendus*, *20*, 1845, 1047.)

C. MARIGNAC: 137.08 (O = 16); 856.77 (O = 100).

Determined by six experiments on the equivalence of silver and barium chloride performed by Pelouze's method, (*vide supra.*) 100 silver were found equivalent to 96.365 barium chloride; extreme difference, 0.038; hence the value taken. Marignac takes Ag = 1349.01, and Cl = 443.2. The barium chloride was purified as follows: Commercial chloride was crystallized from boiling aqueous solution; the crystals were heated to redness, dissolved in boiling water, treated with carbon di-oxide, filtered and crystallized, and these crystals were washed with alcohol and again recrystallized. Determinations were made at each stage and the purification was continued until constant results were obtained. (*Liebig*, *Annal.*, *68*, 1848, 214; *Bibl. Univ.*, *Arch. des Sciences*, *8*, 265.)

H. STRUVE: 136.26 (O = 16).

100 parts of barium chloride gave 112.0938 parts of sulphate as a mean of two experiments; extreme difference, 0.005. S = 32; Cl = 35.4624. (*Liebig*, *Annal.*, *80*, 1851, 204; *Oefversigt af Kongl. vet. Acad. Foehr.*, *6*, 165.)

T. ANDREWS: 137.578 (O = 16).

Andrews obtained this number from two nearly coincident experiments of which he gives no details. (*Brit. Assoc. Rep.*, 1852, pt. 2, 33.)

C. MARIGNAC: 137.16 (O = 16).

Three experiments were made on the titration of air-dried barium chloride in crystals by Pelouze's method, (*vide supra.*) Five grammes of the salt required for precipitation (1) 4.4205; (2) 4.4195; (3) 4.4210 grammes silver. Three experiments were made on the conversion of the same barium chloride into sulphate. Ten grammes of the salt gave (1) 9.543; (2) 9.544; (3) 9.542 grammes sulphate. In each of the latter experiments the water was determined, and was found to vary no more than 0.0005 grammes. Comparison of the two series gives for Ag = 108, S = 16, and O = 8; barium equal to (1) 68.57; (2) 68.61; (3) 68.55; in mean 68.58, or one-half of 137.16. This result is independent of the possible trace of water the chloride might have contained. In another series of three experiments the water was driven off at a low red heat and determined, and the salt analyzed by Pelouze's method. It was proved that barium chloride is not decomposed at the temperature employed. (1) gave 68.61; (2) 58.59; and (3) 68.55, or a mean of 68.583. The salt for the experiments marked (1) was prepared by recrystallization and precipitation with alcohol; that for (2) by a repetition of the same process, and for (3) by resolution of (2) and precipitation with chlorhydric acid gas. Marignac proved that the precipitated argentic chloride contained entirely insignificant traces of barium salt. Cl = 35.5. (*Bibl. Univ., Archives des Sciences, Nouv. Série., 1*, 1858, 209.)

J. DUMAS: 137 (O = 16).

Determined by fifteen experiments on the titration of barium chloride with argentic nitrate, which give a general average of 68.516 with an extreme difference of 0.11. The barium chloride was prepared from pure nitrate and pure carbonate, and from commercially pure chloride after it had been freed from lead by precipitation with barium sulphide. The chloride was precipitated from solution by chlorhydric acid gas and melted in a current of chlorine to prevent oxidation. Ag = 108; Cl = 35.5. (*Annales de Chimie et de Physique*, (3,) *55*, 1859, 137.)

BERYLLIUM.

The atomic heat of beryllium has been determined by J. Emerson-Reynolds by direct comparison with that of silver.

In a calorimetric apparatus constructed for the purpose, the amount of heat given off during cooling by 108 parts of silver heated to 100° was found to be equal to that communicated by a little more than 9.2 parts of beryllium under the same conditions. Assuming the atomic weight of the metal to be 9.2, the atomic heat found would be 5.91. The smallness of this number the observer accounts for by supposing that there was a trace of platinum present introduced by the use of platinum vessels in the course of reduction. (*Phil. Mag.*, (5,) *3*, 1877, 38.)

J. J. BERZELIUS: *14.5* (O = 16).

Berzelius analysed the salt formed by saturating dilute sulphuric acid with beryllium oxide. From the amount of barium sulphate obtained he inferred that the atomic weight of beryllium was 331.261 on the supposition that the oxide was $Be_2 + O_3$ and that the salt was neutral. Berzelius took O = 100; S = 200.75, and Ba = 855.29. [Awdejew having discovered that this salt is basic, this value is reduced to 90.63; or, for O = 16, to 14.5.] Berzelius accepted Awdejew's determination in preference to his own. (*Poggend. Annal.*, *8*, 1826, 187; and *Lehrbuch der Chemie*, 5th ed., *3*, 1225.)

T. THOMSON: 36 (O = 16).

Experiments not given. The value is four times nine, and may have arisen from a mistake as to saturation. (*System of Chem.* 7 ed., *1*, 1831, 459.)

—. AWDEJEW: *13.85* (O = 16); *86.58* (O = 100).

Beryllium sulphate, in chlorhydric acid solution, was decomposed with barium chloride. In the filtrate the excess of barium chloride was precipitated with sulphuric acid, and the beryllium oxide thrown down with ammonia, dried, heated, and weighed. The beryllium sulphate was prepared from pure carbonate by treatment with sulphuric acid and precipitation with alcohol. It was purified by recrystallization. Four experiments were made, the mean of which calculated for S = 201.165, gave Be = 58.084 with an extreme difference of 1.955. (*Poggend. Annal.*, *56*, 1842, 106.) Weeren recalculated these analyses for S = 200 and got 57.72, [or ⅔ of 86.58.] (*Poggend. Annal.*, *92*, 1824, 124.)

J. WEEREN: *13.83* (O = 16); *86.46* (O = 100).

Weeren followed the same method as Awdejew, except that he precipitated the beryllium with ammonium sulphide, the oxide being soluble in excess of ammonia. The mean of four experiments gave 57.64, the extreme difference being 1.52 for O = 100, [57.64 is $\frac{2}{3}$ of 86.46.] Weeren took S = 200. (*Poggend. Annal.*, *92*, 1854, 124.)

G. KLATZO: *13.89* (O = 16).

Klatzo made five analyses of the sulphates containing seven and four molecules of water, precipitating the sulphuric acid as barium sulphate, and the beryllium as oxide by means of ammonia. From a comparison of the sum of the oxide found in all the analyses with the total amount of barium sulphate found, Klatzo deduces Be = 9.227, for Ba = 137, and S = 32. [If Ba is taken equal to 137.16, and S = 32.07, and if each of the analyses is calculated for itself, Be = 13.89. The extreme difference is 0.45.] The sulphates were purified by recrystallization, and treatment with alcohol. (*Erdmann's Journ. für Prak. Chemie*, *106*, 1868, 227; *Klatzo*, *Ueber die Constitution der Beryllerde*, *Dorpat*, 1868.)

L. F. Nilson and O. Pettersson have redetermined the specific heat of beryllium within a few weeks. They find the specific heat 0.4079, corresponding to a trivalent metal and a sesqui-oxide. The investigation seems to have been made with great care, while that of Emerson-Reynolds was merely preliminary. (*Berlin*, *Bericht der chem. Ges.*, *11*, 1878, 386.)

BISMUTH.

Dulong and Petit, Regnault, and Kopp, have determined the specific heat of Bismuth. It corresponds to an atomic weight of about 210. (*Gmelin-Kraut*, *l. c.*)

P. LAGERHJELM: *212.86* (O = 16); 1330.377 (O = 100).

Metallic Bismuth was oxidized in a weighed vessel by nitric acid, and the nitric acid expelled by heat. 10 grammes of bismuth gave 11.1275 oxide. (*Berzelius' Lehrbuch der Chemie*, 5th ed., *3*, 1216; *Stockholm*, *Akad. Handl.*, *34*, 1813, 219.)

R. SCHNEIDER: *208* (O = 16); 1299.98 (O = 100).

Determined by eight experiments on the conversion of metallic bismuth into oxide by solution in nitric acid and decomposition of the nitrate in the same vessel. The escaping gases were led through nitric acid, and the bismuth caught in this way was separately converted into oxide and weighed. In four experiments the bismuth was prepared by the reduction of basic nitrate, and for the other four by the reduction in hydrogen of the oxide formed in those which preceded. 100 bismuth oxide were found to contain a mean of 89.655 metal; extreme difference, 0.048. (*Poggend. Annal.*, *82*, 1851, 303.)

J. DUMAS: 210.44 (O = 16).

Determined by seven experiments on bismuth chloride, which was decomposed in solution by sodium carbonate, and the sodium chloride thus formed titrated with silver solution. The value taken is the mean result. The extreme difference is 1.12. Dumas takes Ag = 108, and Cl = 35.5. The bismuth chloride was prepared by the action of chlorine on bismuth, and was purified by fractional distillation over bismuth. That employed in the experiments was colorless. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 176.)

BORON.

The specific gravities of a number of volatile compounds of boron have been determined by Dumas, Woehler and Deville, and others, and correspond to an atomic weight of about 11. (*Gmelin-Kraut*, *l. c.*; *L. Meyer*, *l. c.*)

H. F. Weber has discovered that the specific heat of boron rises rapidly with the temperature, becoming nearly constant at 600°. Above this temperature its specific heat is 0.5, and its atomic heat 5.5. (*Poggend. Annal.*, *154*, 1875, 575.)

J. J. BERZELIUS: 11.01 (O = 16).

Davy's investigations having shown that boracic acid contains about 68 per cent. oxygen, and having thus established the formula of borax, Berzelius determined the atomic weight from the water contents of that salt. He found in three experiments, without variation, 47.1 per cent. Gmelin-Kraut recalculates this composition with Stas' atomic

weights, and gets the value given. (*Poggend. Annal.*, *8*, 1826, 19.)

A. LAURENT: 10.86 (O = 16).

Laurent found that borax retains some water even when melted, which, however, can be expelled by the addition of iceland spar. By repeating Berzelius' experiments, and adding a known weight of spar, he found the water contents in two experiments 47.15 and 47.20. He did not regard the experiments as accurate. Gmelin-Kraut recalculates these data with Stas' atomic weights, and gets B = 10.91 and 10.81. (*Paris Comptes Rendus*, *29*, 1849, 5.)

WOEHLER and DEVILLE: 10.87 (O = 16).

These chemists titrated the bromide and the chloride of boron with argentic nitrate. They do not offer the analyses as atomic weight determinations, but Dumas applies the data to this object. Taking Ag = 108, and Cl = 35.5, Dumas calculates from the analysis of the chloride prepared by the action of H Cl on B, B = 11; from the analysis of the chloride prepared by the action of Cl on B, B = 10.6; from the analysis of the bromide prepared by the action of bromine on boron, B = 11. (*Annal. de Chimie et de Physique*, (3,) *52*, 1858, 88; *55*, 1859, 129.)

T. THOMSON: *10.67* (O = 16).

Thomson supposed boracic acid to be composed of one atom of boron and two of oxygen, and concluded from Davy's and his own experiments that the atom of B was exactly equal to that of O. For the correct composition of the acid his value must be reduced one-third. (*System of Chem.*, 7th ed., *1*, 1831, 214.)

BROMINE.

Mitscherlich determined the vapor density of bromine, and Regnault the specific heat in a solid condition at very low temperatures. Both of these constants correspond to an atomic weight of 80. (*Gmelin-Kraut, l. c.; L. Meyer, l. c.*)

A. J. BALARD: *75* (O = 16); 468.85 (O = 100).

1.27 potassium bromide decomposed with sulphuric acid

gave a residue of 0.973 potassic sulphate. [If this analysis is calculated with Stas' atomic weights, it gives Br = 74.65.] In another experiment 100 parts of argentic bromide reduced with zinc, the excess of which was extracted with sulphuric acid, gave 58.9 parts silver. [Calculated with Stas' data this gives Br = 75.3.] Balard mentions no special precautions in the preparation of his salts for this determination. (*Annal. de Chimie et de Physique*, *32*, 1826, 357, 362.)

J. LIEBIG: *75.29* (O = 16); 470.55 (O = 100).

2.521 potassic bromide precipitated with argentic nitrate gave 4.041 argentic bromide. The potassic bromide was obtained by adding potassic hydrate to an alcoholic solution of bromine until the solution began to lose color. (*Annal. de Chimie et de Physique*, *33*, 1826, 331.)

J. J. BERZELIUS: *78.264* (O = 16); 489.15 (O = 100).

Berzelius suspected that insufficient precautions had been taken in the preceding determinations to get rid of chlorine. He washed bromine for a long time, and converted it into zinc bromide and ammonium bromide. These salts he partially precipitated with argentic nitrate to get rid of chlorine. From the filtrate he precipitated argentic bromide which he washed, dried, and melted. 7.202 of this bromide, decomposed in a current of chlorine, yielded 5.546 argentic chloride; 7.8805 bromide gave 6.069 chloride. If Ag = 1351.607, and Cl = 442.652, the mean value of Br is as above; difference, 0.09. (*Poggend. Annal.*, *14*, 1828, 565; *Kongl. vet. Akad. Handl.*, 1828.)

C. LOEWIG: 75.76 (O = 16).

According to Gmelin-Kraut, *Handbuch der Chemie*, the determination was published in a treatise entitled *Brom und Seine Chemische Verhältnisse*, *Heidelberg*, 1829.

C. MARIGNAC: 79.957 (O = 16).

In three experiments a known weight of silver was dissolved in nitric acid, precipitated with potassium bromide, and the argentum bromide dried at 200° and weighed. [For Ag = 107.93 these experiments give Br = 79.938, with an extreme difference of 0.018.] *In vacuo* this result is, according to Stas, 79.968. In seven experiments a known weight of silver was precipitated by a determinate amount of potassic bromide by titration. [If K = 39.137, and Ag = 107.93,

this gives bromine = 79.924 with an extreme difference of 0.046.] *In vacuo* this becomes, according to Stas, 79.945. In four experiments potassium bromate was decomposed by heat, and the potassic bromide weighed. [For K = 39.137 these experiments give bromine at 80.11 with an extreme difference of 0.56. These latter are evidently much less accurate than the preceding, and I have therefore averaged the first and second series *in vacuo*.] The KBr was prepared by heating bromate purified by recrystallization. (*Berzelius' Lehrbuch der Chemie*, 5th ed., *3*, 1194; *Bibl. Univ.*, *46*, 1843, 357.)

W. WALLACE: 79.74 (O = 16).

Determined by analysis of arsenic ter-bromide, by titration with argentic nitrate, according to the method of Pelouze, (see arsenic, Pelouze's determination.) Three experiments were made, giving a mean of 79.738; extreme difference, 0.051. As = 75; Ag = 107.97. The arsenic and bromine were directly combined, and the compound was purified by fractional distillation and recrystallization. (*Phil. Mag.*, (4,) *18*, 1859, 279.)

J. DUMAS: 80 (O = 16).

Determined by three experiments on the conversion of argentum bromide into chloride in a current of dry chlorine. The mean is 80.03; the extreme difference is 0.18. Silver is taken at 108, and chlorine at 35.5. The argentum bromide was prepared with bromine free from iodine, and was purified from chlorine by digestion with argentum bromide. (*Annal. de Chemie et de Physique*, (3,) *55*, 1859, 162.)

J. S. STAS: 79.952 (O = 16).

Four complete syntheses (the weight of each of the constituents, and of the compound being determined) were made of argentum bromide, a known weight of silver being converted into sulphate, and precipitated with a known weight of bromine which had been converted into hydrobromic acid. The mean result was that 100 Ag = 74.0805 Br; with an extreme difference of 0.004. Two analyses of argentic bromate, made by reducing the salt in suspension with sulphurous acid, gave for the molecular weight of the bromide 187.84, and 187.90, mean 187.87. A comparison of these data gives Br = 79.940. [This, I think, must be a misprint for 79.949.] Fourteen experiments were made on the equivalence of KBr and Ag by Pelouze's method, (see

As, Pelouze's determination.) The mean result was that 100 Ag = 110.345 KBr; extreme difference, 0.029. This gives Br = 79.958 for Ag = 107.93, and K = 39.137. The bromate of silver was prepared from potassic bromate and silver salts. For the preparation of Ag see Stas' determination of it. The potassic bromate was prepared by the action of chlorine on a mixture of KBr and KHO. The bromide was prepared by the action of heat on bromate, by treating bromine with KHO, and in other ways. No reagents were probably ever prepared with such care as those employed in this and the accompanying determinations. The weights are all *in vacuo*. (*Stas, Untersuch. über Chem. Proport., Leipzig*, 1867.)

CADMIUM.

Regnault, Kopp, and Bunsen have determined the specific heat of cadmium, which corresponds to an atomic weight of 112. Deville and Troost determined the density of cadmium vapor at above 1000°. It answers to an atomic weight of 114. (*Gmelin-Kraut, l. c.; L. Meyer, l. c.*)

F. Stromeyer: *111.48* (O = 16); 696.767 (O = 100).

Stromeyer found that 100 parts of cadmium combine with 14.352 parts of oxygen to form the oxide. (*Berzelius' Lehrbuch der Chemie*, 5th ed., *3*, 1219; *Schweigger's Journ.*, *22*, 1818, 362.)

T. Thomson: *112* (O = 16); 700 (O = 100).

Thomson says that he has shown this to be the true value by analysis of the sulphate in two different states. (*System of Chem.*, 7th ed., *1*, 1831, 555.)

K. von Hauer: 112 (O = 16); 700 (O = 100).

Determined by nine experiments on the reduction of cadmium sulphate to sulphide in a current of hydrogen sulphide under pressure. The mean of the experiments gave Cd = 55.999; extreme difference, 0.16. Von Hauer took S = 16. The sulphate was purified by repeated recrystallizations and by conversion into oxide. It was dried at 200°. The sulphide was in each case carefully examined for undecomposed sulphate. (*Erdmann's Journ. für Prak. Chem.*, *72*, 1857, 346.)

J. DUMAS: 112.24 (O = 16).

Determined by six experiments on the titration of cadmium chloride with argentic nitrate. The mean of all the experiments was Cd = 56.12; extreme difference, 0.49. The third experiment varies considerably from the rest, and Dumas seems inclined to omit it in the average. If it is left out, the mean becomes 56.06; extreme difference, 0.29. Dumas takes Cl = 35.5; Ag = 108. The cadmium chloride was prepared in two lots by solution of cadmium in chlorhydric acid, evaporation and melting for several hours in a current of chlorhydric acid gas. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 158.)

E. LENSSEN: 112.06 (O = 16).

Three experiments were made on the decomposition of cadmium oxalate, the salt and the resulting oxide being weighed. The mean result was Cd = 56.03; extreme difference, 0.19. C = 6. The oxalate was prepared from pure chloride by precipitation with oxalic acid, washing and drying at 150°. It was carefully tested, and was found to be anhydrous. (*Erdmann's Journ. für Prak. Chemie*, *79*, 1860, 281.

CÆSIUM.

The great similarity between cæsium and the other alkaline metals renders the deduction of its atomic weight from its equivalent sufficiently certain.

KIRCHHOFF and BUNSEN: 123.35 (O = 16).

Determined by three experiments on the analysis of the chloride with argentic nitrate. The value is the mean; extreme difference, 0.13. The cæsium was separated from the other alkalies by extracting a mixture of oxides and carbonates with alcohol. It was converted into chloride by precipitation with platinum chloride, reduction of the double chloride in hydrogen and solution. These operations were repeated until the cæsium salt gave sensibly the same results after successive purifications. Its purity was also tested spectroscopically. Silver was taken at 107.94, and chlorine at 35.46. (*Poggend. Annal.*, *113*, 1861, 363.)

JOHNSON and ALLEN: 133 (O = 16).

Determined by four experiments on the precipitation of cæsium chloride with argentic nitrate. The mean result was Cs = 133.036; the extreme difference, 0.842. Ag = 107.94; Cl = 35.46. Cæsium and rubidium were separated by partial crystallization of their bitartrates. The cæsium bitartrate was converted into chloride by precipitation with platinum chloride, reduction and solution. The nitrate formed on the precipitation of the cæsium chloride with silver was reconverted into cæsium chloride and redetermined, and so on. The purity of the salt was tested spectroscopically. (*Silliman's Amer. Journ.*, (2,) *35*, 1863, 96.)

R. W. BUNSEN: 133 (O = 16).

Determined by three experiments on the precipitation of cæsium chloride with argentic nitrate. The mean result was 132.99; extreme difference, 0.02. Ag = 107.94; Cl = 35.46. In order to prepare pure chloride, a mixture of cæsium and rubidium salts was converted into carbonates, a little more tartaric acid was added than was necessary to form acid tartrate with the rubidium and neutral tartrate with the cæsium, and the mixture was exposed on a filter to the action of a saturated atmosphere of aqueous vapor. The cæsium salt is deliquescent, and gradually passes through the filter, while the rubidium salt is unaffected. The cæsium tartrate was turned into pure chloride by repeated precipitation with platinum chloride, reduction in hydrogen and solution. The determinations were made on the product of successive purifications, and only those were taken into consideration which were made after analysis showed a constant composition. The spectroscope was employed to test the purity of the salt. (*Poggend. Annal.*, *119*, 1863, 5.)

—. MERCER: 133 (O = 16).

The fact of this determination, without details, is mentioned by Frankland. (*Chem. News*, *8*, 1863, 18.)

R. GODEFFROY: 132.557 (O = 16).

Derived from the mean of four analyses of cæsium chloride with argentic nitrate, the extreme difference being 0.185. Cl = 35.5; Ag = 108. The cæsium was separated from the other alkalies by the fractional crystallization of their alums continued until the cæsium compound was

spectroscopically pure. The aluminium was removed with ammonia, the sulphuric acid with barium chloride and traces of barium with ammonium carbonate. The cæsium chloride, which was not deliquescent, was dried at 150°. (*Liebig's Annal.*, *181*, 1876, 185.)

CALCIUM.

Bunsen has determined the specific heat of calcium. It corresponds to an atomic weight of 40. (*Gmelin-Kraut, l. c.*)

F. H. WOLLASTON: *40.736* (O = 16); 254.6 (O = 100).

Wollaston found that 43.7 parts of carbon di-oxide saturated 56.3 parts of lime. If C = 75.4, the value follows. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *40.32* (O = 16); 252.075 (O = 100).

301 parts of anhydrous calcium chloride gave 775 parts argentic chloride. If Cl = 443.28 and Ag = 1349.66 the value follows. This analysis, made in 1818, was erroneously calculated from a mistake in setting down its results and the atomic weight of Ca was taken at 256.019. (*Poggend. Annal.*, *8*, 1826, 189; and *Lehrbuch der Chemie*, 5th ed., *3*, 1227.)

J. DUMAS: 40 (O = 16).

Three experiments were made on the calcination of calcium carbonate which contained 0.03 per cent. of ferric oxide and silicic acid. The weight of the residue was in mean 56.07, or, subtracting 0.03, 56.04, with an extreme difference of 0.08. These figures give almost exactly 40. The weighings are reduced to vacuum. (*Paris Comptes Rendus*, *14*, 1842, 537.)

—. SALVETAT: 40 (O = 16); 250 (O = 100).

It is to be inferred from the context that this determination was made from the loss of weight ensuing on the decomposition of calcium carbonate by heat or sulphuric acid. (*Paris Comptes Rendus*, *17*, 1843, 318.)

C. MARIGNAC: *40.208* (O = 16); 251.3 (O = 100).

Determined by precipitating calcium chloride with argentic nitrate; Ag = 1349.01; Cl = 443.2. Marignac laid no weight on this determination finding it impossible to prepare calcium chloride which did not show an alkaline reaction. The presence of caustic lime would make the result erroneously high; no doubt Berzelius' early analysis was defective from the same cause. (*Berzelius' Jahresbericht*, *24*, 1844, 103; *Bibl. Univ.*, *46*, 1843, 367.)

ERDMANN and MARCHAND: 40.007 (O = 100).

Four experiments were made on the calcination of calcium carbonate enclosed in a double platinum crucible in a wind-furnace, till the weight was constant. A mean of 56 per cent. calcium oxide was found with an extreme difference of 0.05. This gives Ca = 40 for C = 12. Two experiments were made by decomposing calcium carbonate by sulphuric acid. These gave a mean of 43.99 carbonic acid; difference, 0.02. The value taken is the mean of all experiments. The carbonate was prepared by precipitating calcic chloride with ammonium carbonate, and drying at 160° to 180°. Confirmatory experiments were made on iceland spar. The weighings are reduced to vacuum. (*Erdmann's Journ. für Prak. Chem.*, *26*, 1842, 472.)

Berzelius maintained that Erdmann and Marchand employed material containing water, chlorine and magnesium. Erdmann and Marchand answered that there could be no magnesium and was no chlorine but that they had convinced themselves that spar is the only compound of certain and constant composition. Berzelius replied that they then admitted that their carbonate contained water. Erdmann and Marchand appealed to their experiments on spar, upon which Berzelius made experiments showing that spar, too, retains water at 200°. This Erdmann and Marchand denied and finally assert that all the carbonic acid is not driven off at any attainable temperature, and that their results were therefore too high instead of being too low. The error they estimate to exactly cover the difference between their averages and 40. (*Erdmann's Journ. für Prak. Chem.*, *31*, 1844, 257; *37*, 1846, 75; *50*, 1850, 237.)

ERDMANN and MARCHAND: *40.062* (O = 16); 250.39 (O = 100).

The spar experiments referred to above. Six analyses were made as before, giving a mean of 56.028 oxide; extreme

difference 0.047. (*Erdmann's Journ. für Prak. Chemie*, *31*, 1844, 268.) Another experiment, in which the absence of water was proved, gave 56.03 lime. The weighings are reduced to vacuum. (*Erdmann's Journ. für Prak. Chem.*, *37*, 1846, 77.)

J. J. BERZELIUS: *40.264* (O = 16); 251.651 (O = 100).

Five experiments were made on the conversion of caustic lime into sulphate. The value is the mean for S = 200.75; extreme difference 0.962 for O = 100. The lime was carefully purified and burnt, but Berzelius says nothing of testing it for carbonic acid, upon which Erdmann and Marchand found an objection. Berzelius expresses himself ill satisfied with the results. (*Liebig's Annal.*, *46*, 1843, 241; also *Lehrbuch der Chemie*, 5th ed., *3*, 1228.)

J. DUMAS: 40.02 (O = 16).

Five experiments were made on the titration of calcium chloride with argentic nitrate. They give a mean of 20.065, but Dumas considers only three of them as entitled to a voice. These give 20.01; extreme difference, 0.03. The calcium chloride was prepared by dissolving marble in chlorhydric acid, digestion with lime water, filtration, evaporation, treatment with chlorhydric acid and heating in a current of chlorine. For the three experiments averaged the chloride was kept melted in the current of gas for from 8 to 10 hours. Ag = 108; Cl = 35.5. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 129.)

CARBON.

The specific gravity of gaseous carbon compounds shows that the atomic weight must be nearly 12. (*Gmelin-Kraut*, *l. c.*) Weber has shown that the specific heat of carbon at high temperatures obeys Dulong and Petit's law.

F. H. WOLLASTON: *12.064* (O = 16); 75.4 (O = 100).

Biot and Arago found the specific gravity of carbon dioxide 1.5196, and that of oxygen, 1.1036. Calculation from these data gives the value. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: earlier determinations.

In 1817 Berzelius attempted to determine the atomic weight of carbon by two analyses of plumbic carbonate. [These analyses calculated for Pb = 206.926 (Stas,) give C = 11.998 and 11.984, or 74.99 and 74.90.] Considering the difference too great, he calculated the atomic weight from Biot and Arago's determination of the specific gravities of carbon di-oxide and oxygen, 1.10359 and 1.51961. Berzelius gives 75.33 as the result; [I make it 75.394.] Subsequently, (1819,) Berzelius and Dulong determined these specific gravities more accurately at 1.524 and 1.1026 whence he calculated C = 76.437. This number was accepted until Dumas showed it to be false, although in the mean time carbon di-oxide had been shown to be a condensible gas. According to Dumas, Berzelius at one time accepted a value 76.52 of which I have found no account. In Berzelius' *Lehrbuch*, *3*, 1174, 76.48 is a misprint for 76.437. (*Berzelius' Lehrbuch der Chemie*, 5th ed., *3*, 1197, *et passim*.)

T. THOMSON: *12* (O = 16); 75 (O = 100).

Thomson found the specific gravity of carbon di-oxide 1.52673. Assuming the specific gravity of oxygen at 1.1111, chiefly to accord with the supposition that air is a compound containing 20 per cent. of oxygen, he calculates the atomic weight of carbon at 75. (*Erdmann's Journ. für Prak. Chem.*, *8*, 1836, 372; *Records of General Science, by R. D. Thomson*, 1836, 179.)

J. DUMAS: about *12.16* (O = 16); 76 (O = 100).

From analysis of well crystallized naphthaline, Dumas infers that the atomic weight of carbon cannot be so high as 76.44, and must be nearly as above. (*Poggend. Annal.*, *44*, 1838, 110.)

J. J. BERZELIUS: *12.23* (O = 16); 76.458 (O = 100).

One experiment was made on the decomposition of plumbic carbonate by heat, which gave C = 76.405. [If Pb = 206.926, the data give C = 12.185, or 76.157.] Another experiment was made on the oxalate, which gave C = 76.511. Berzelius regards these results as confirmatory of the value 76.438. The plumbic carbonate was prepared by precipitating the nitrate with ammonium carbonate. The oxalate was obtained by decomposing the acetate with oxalic acid. (*Liebig's Annal.*, *30*, 1839, 241.)

G. FOWNES: 12.12 (O = 16).

Determined by three analyses of naphthaline with cupric oxide, the usual precautions being observed. The value is the mean; extreme difference, 0.14. The naphthaline was purified by slow sublimation in a florence flask, and was brilliantly white. Fownes does not regard his results as conclusive as to the exact value. (*Phil. Mag.*, (3,) *15*, 1839, 62.)

E. MITSCHERLICH: *12.016* (O = 16); 75.1 (O = 100).

Experiments made on the analysis of naphthaline by the ordinary method of organic analysis gave never more than 75.2, and those which seemed most accurate very nearly 75. (*Mitscherlich's Lehrbuch der Chemie*, 4th ed., *1*, 1844, 595.)

DUMAS and STAS: *12* (O = 16); 75 (O = 100).

Determined by fourteen experiments on the combustion of carbon in oxygen, the resulting carbon di-oxide being weighed. In five cases natural graphite was employed, and in four graphite from charcoal pig-iron. Both were purified by treatment with acid and heating in chlorine. The necessary oxygen was developed in the combustion-tube from potassic chlorate and cupric oxide. In five experiments diamond was employed, and the oxygen was furnished from a gasometer. The oxygen was displaced by air, especially purified from carbon di-oxide by milk of lime. The products of combustion were collected in tubes filled with pumice stone moistened with sulphuric acid, Liebig potash-bulbs and tubes filled with dry potash. The mean of the experiments on graphite gave C = 74.982; those on diamond gave 75.005; the extreme difference was 0.238. The observers point out that the result would not be affected by reduction to vacuum. (*Annal. de Chimie et de Physique*, (3,) *1*, 1841, 5.)

Liebig thinks that potash must have been volatilized, and says that there is no assurance that the oxygen was completely expelled by air. He also points out that the analyses of camphor and benzoic acid, accompanying the investigation, show an excess of carbon for C = 75. (*Liebig's Annal.*, *38*, 1841, 195.)

ERDMANN and MARCHAND: *12.009* (O = 16); 75.054 (O = 100).

Erdmann and Marchand repeated Dumas' and Stas' experiments. Five experiments on diamond gave C = 75.028;

extreme difference, 0.38. Three experiments on natural and one on artificial graphite gave C = 75.087; extreme difference, 0.13. The number is the mean of all experiments. Erdmann and Marchand adopt 75. Calcium chloride was used in these experiments instead of sulphuric acid to avoid objections as to the possible volatility of the acid. (*Erdmann's Journ. für Prak. Chem.*, *23*, 1841, 159.)

BERZELIUS and LIEBIG and REDTENBACHER: *12.119* (O = 16); 75.741 (O = 100).

Five analyses by Berzelius of the tartrate of lead, the decomposition being effected by heat, gave 62.7431 per cent. plumbic oxide; extreme difference, 0.045. Several analyses of plumbic racemate gave a mean of 62.75 per cent. oxide; extreme difference, 0.05. The salts were prepared by fractional precipitation of plumbic acetate with tartaric and racemic acids respectively. They were dried at 100°. (*Poggend. Annal.*, *19*, 1830, 306.) From the analyses of the tartrate Liebig and Redtenbacher calculate C = 75.771, and from the racemate 75.711, taking Pb = 1294.489 and H = 6.2394. (*Liebig's Annal.*, *38*, 1841, 137.)

LIEBIG and REDTENBACHER: *12.137* (O = 16); 75.854 (O = 100).

Determined by decomposing known weights of organic salts of silver in a covered crucible by heat and weighing the silver. Five analyses of each of the following salts showed that 18.6113 Ag = 28.8098 acetate; 9.6171 Ag = 16.223 tartrate; 16.2641 Ag = 27.438 racemate; 16.0596 Ag = 25.9019 malate. If Ag = 1351.607 and H = 6.2394, the above value for C follows, with an extreme difference for the 20 analyses of 0.765, (O = 100.) The figures are all calculated for vacuum. [If Ag = 107.93 and H = 1.0025, the average number obtained from the mean of each set of analyses gives C = 12.06865 or 75.429.] The acetate was prepared by partially neutralizing pure acetic acid with ammonia, precipitating with argentic nitrate and recrystallizing the salt from hot aqueous solution. The crystals were dried at 103°. The acetic acid was prepared from plumbic acetate. The tartrate was prepared by adding tartrate of sodium and potassium to a hot (80° to 85°) dilute solution of argentic nitrate till a small permanent precipitate was formed, and cooling the solution. The racemate was prepared from pure acid racemate of ammonium like the tartrate. The malate was prepared from calcium

malate and argentic nitrate. The salt thus obtained was dissolved in nitric acid, and reprecipitated with ammonia added drop by drop, not to complete neutralization, washed and dried. (*Liebig's Annal.*, *38*, 1841, 139.)

A. Strecker recalculated Liebig and Redtenbacher's analyses given above, independently of the atomic weight of silver, from the difference in their atomic composition, employing the method of least squares. He found $C = 75.415 \pm 0.061$, or 12.066 ± 0.01. In the same way, and from the same analyses he calculated the atomic weight of silver at 1348.79, or 107.9032. [The close coincidence between this result and Stas', is certainly worthy of remark.] (*Liebig's Annal.*, *59*, 1846, 280.)

Marignac repeated Liebig and Redtenbacher's experiments and got almost the same results, but, by varying the method so as to preclude loss by spirting, different ones. (*Liebig's Annal.*, *59*, 1846, 287.)

Stas had the same experience as Marignac, and also ascribes Liebig and Redtenbacher's high results to loss by spirting. (*Bulletin de l'Acad. Roy. des Sciences de Belgique*, *16*, 1849, 9.)

C. Marignac: *11.986* ($O = 16$).

Determined by three analyses of the acetate of silver. The salt was decomposed by heat in a tube in such a way that the products of decomposition were forced to pass through porous silver, and loss by spirting was impossible. 100 parts of the salt were found to contain a mean of 64.664 silver, with an extreme difference of 0.005 *in vacuo*. [If $Ag = 107.93$, these figures give the above value.] Marignac regards the analysis as a confirmation of Dumas and Stas' determination. The acetate was prepared by solution of argentic carbonate in acetic acid and successive recrystallizations. (*Liebig's Annal.*, *59*, 1846, 287; *Bibl. Univ.*, *Arch. des Sciences*, *1*. 1846.)

Strecker believes that the silver in Marignac's determination must have retained carbon. (*Ibid.* 284.)

F. von Wrede: 12.019 ($O = 16$); 75.12 ($O = 100$).

Von Wrede determined the specific gravity of carbon dioxide, taking into consideration its variation from the law of Marriotte. He found it equal to $1.52037 \frac{1 + 0.0049.p.}{1 + at.}$ He also found the specific gravity of oxygen 1.1052 and

that of carbonic oxide 0.96779. Comparison gives C = 75.11 to 75.14. (*Berzelius' Jahresbericht*, *22*, 1842, 72.) Berzelius adopted this determination.

According to Gmelin-Kraut, *1*, (2,) 70, Regnault's value for the specific gravity of oxygen combined with von Wrede's for carbon di-oxide gives C = 12.0037, and with that for carbonic oxide C = 12.0105.

J. S. Stas: *12.005* (O = 16); *75.029* (O = 100).

Determined by passing carbonic oxide over a known weight of pure cupric oxide, and weighing the carbon di-oxide formed. Stas got from eight experiments C = 74.993 to 75.055. [The number taken is the mean of the results, which is misprinted in Stas' paper 75.039.] The carbonic oxide was prepared from oxalic acid by the action of sulphuric acid. It was purified from carbon di-oxide by passing through potash tubes, and from oxygen by passing over hot copper filings, and was kept in a gasometer over water, in which was dissolved a solution of stannous oxide in potash. The cupric oxide was prepared by igniting pure cupric nitrate. The carbonic acid formed in the experiments was caught in potash and sulphuric acid tubes. The amount of carbon di-oxide weighed was from 23 to 67 grammes. The weighings are reduced to vacuum. (*Bulletin de l'Acad. Roy. des Sciences de Belgique*, *16*, 1849, 9.)

GRAPHON.

B. C. Brodie: 33 (O = 16).

By the action of potassic chlorate and nitric acid on graphite, Brodie obtained a compound of carbon, oxygen and hydrogen containing 11 atoms of carbon, and by the action of heat on this substance two others containing, respectively, 22 and 66 atoms. The first of these is analogous to the hydrated oxide of silicon obtained by Buff and Woehler, if Si = 21. From this fact, and the specific heat of graphite, Brodie concludes that the atomic weight of the graphitic form of C is 33. (*Phil. Trans.*, *149*, 1859, 249.) Graham-Otto points out that if Si = 28, graphon must be 44, and that, in that case, the argument from the specific heat loses its applicability.

CERIUM.

The specific heat of metallic cerium, as determined by W. F. Hillebrand, is 0.04479, and the atomic heat 6.18 if the atomic weight is 138. (*Poggend. Annal.*, *158*, 1876, 86.)

It is well known that cerium is always accompanied in nature by lanthanium and didymium. The former was discovered in 1839, and the latter in 1843, both by Mosander.

W. Hisinger: *137.93* (O = 16).

According to Hisinger, as reported by Berzelius, the lower oxide of cerium contains 14.821 O per 100 Ce, giving the atomic weight at 574.718 for O = 100, if the lower oxide is regarded as a protoxide. (*Poggend. Annal.*, *8*, 1826, 186.)

T. Thomson: *150* (O = 16).

Thomson analysed the sulphate and obtained for cerium the value 625, (O = 100.) [He probably took barium = 70.] (*System of Chem.*, 7th ed., *1*, 1831, 466.)

F. J. Otto: *138.91* (O = 16).

According to Gmelin, Otto found in an approximate determination Ce = 578.8, and recorded it in his revised translation of Graham's Chemistry, *1*, 1840, 222.

A. Beringer: *138.48* (O = 16).

[Three analyses of cerous chloride with silver give the atomic weight of cerium at 576.375, or 92.22, if Ag = 107.93, and Cl = 35.457. Inconsistent results are given for an analysis of the sulphide.] Three analyses of the sulphate in which the oxide was determined, gave 57.4717 per cent. so-called protoxide, [or Ce = 576.31, or 92.21, if S = 32.0742.] Analysis of the formate gave Ce = 577.04 for C = 75.85. The material for the preparations was ceric oxide obtained from cerite, and purified from lanthanium by digestion with very dilute nitric acid. The lower oxide was assumed to be Ce O. (*Liebig's Annal.*, *42*, 1842, 134.)

R. Hermann: *138* (O = 16).

The lower oxide was assumed to be Ce O. 23.523 parts of anhydrous cerous sulphate gave 29.160 parts of barium sulphate, giving Ce = 575, for O = 100, Ba = 856.88, and S = 201.16. The salt was obtained by precipitating basic

sulphate from a sulphuric solution of the cerite oxides, and converting this precipitate into the neutral salt. (*Erdmann's Journ. für Prak, Chem.*, *30*, 1843, 184.)

C. RAMMELSBERG: *137.93* (O = 16).

Hermann states that Rammelsberg experimented on cerium salts free from lanthanium, and got Ce = 574.7, the lower oxide being supposed to contain one atom of oxygen. [I cannot find the original paper.] (*Erdmann's Journ. für Prak. Chem.*, *30*, 1843, 184.)

C. MARIGNAC: *141.79* (O = 16).

The result of seven experiments on the titration of cerous sulphate, prepared from basic sulphate, with barium chloride. (*Erdmann's Journ. für Prak. Chem.*, *48*, 1849, 406; *Bibl. Univ. Arch des Sciences*, *8*, 265.) Marignac subsequently made experiments which showed these results to be too high from the impurity of the barium sulphate precipitate, (see note to Turner's determination of Barium,) and that the number 575 (for O = 100 and cerous oxide Ce O) was more probable. (*Annal. de Chimie et de Physique*, (3,) *38*, 1853, 148.)

T. KJERULF: *174.56*.

Kjerulf obtained, by three organic analyses of cerium oxalate, Ce = 727.33 on the protoxide theory, O = 100. The salt was prepared by dissolving cerium oxide in oxalic acid. (*Liebig's Annal.*, *87*, 1853, 12.) Bunsen points out that this must have been a basic salt. (*Ibid*, *105*, 1858, 50.)

R. BUNSEN and J. JEGEL: *138.192* (O = 16).

The lower oxide was presumed to contain one atom of oxygen. In two experiments cerous sulphate was decomposed with ammonium oxalate. The sulphuric acid thus liberated was determined with barium sulphate; the cerium oxalate precipitate was decomposed by heat with the formation of ceric oxide, which was weighed and the additional oxygen, introduced by heating, determined by iodometric titration. The salt was not anhydrous; the water contents was estimated by difference. The experiments gave respectively 57.49 and 57.46 per cent cerous oxide in the anhydrous salt, or Ce = 576.3 and 575.25 if S = 200. One experiment was made on hydrous cerium oxalate. The cerous oxide was found as before; the water was determined and the

oxalic acid was estimated by difference. This gave 60.02 per cent. cerous oxide, calculated for the anhydrous salt, or Ce = 575.65. The salts were prepared from cerite as follows: the mineral was digested with sulphuric acid, the sulphates formed were leached with water and with dilute nitric acid; this solution was treated with hydrogen sulphide, chlorhydric acid was added and cerium oxalate was precipitated. The oxalate was heated with magnesia to convert the cerium into the higher oxide, which was dissolved in concentrated nitric acid. After diluting the solution, chemically pure basic sulphate was precipitated. In the preparation of cerous sulphate and oxalate oxidation was prevented by the action of sulphurous acid. (*Liebig's Annal.*, *105*, 1858, 45.)

C. RAMMELSBERG: *138.216* (O = 16).

One experiment on the organic analysis of cerium oxalate by heating in a current of oxygen behind copper oxide gave Ce = 575.9, (O = 100,) or 92.144, (O = 16,) cerous oxide being regarded as Ce O. Rammelsberg does not adopt his own, but Hermann's determination. (*Poggend. Annal.*, *108*, 1859, 44.)

C. WOLF: *136.992* (O = 16).

Determined from experiments on the sulphate, prepared and analyzed as by Bunsen and Jegel. Wolf purified the basic sulphate by solution in nitric acid and reprecipitation in hot water, aided by recrystallizations. He found that the oftener these processes were repeated the smaller was the atomic weight resulting from the analysis. The purifications were repeated until the salt was spectroscopically free from didymium, and was perfectly white, (that employed by other investigators had been yellowish or buff.) The value taken, 45.664, [or $\frac{1}{3}$ of 136.992,] was the smallest and last value reached. The investigation was made in Bunsen's laboratory. (*Silliman's Am. Journ.*, (2,) *46*, 1868, 53.)

C. H. WING: *137.01* (O = 16).

Two experiments were made on the decomposition of hydrous cerium sulphate with oxalic acid, the cerium oxalate being converted into ceric oxide by heat. The amount of cerous oxide in the ceric oxide was calculated according to Wolf's results, giving for the atomic weight of cerium 45.64 and 45.69, S being 32. The cerium was six times recon-

verted into basic sulphate, and repeated recrystallizations were made. The salt was white and spectroscopically pure. The determination was made in Gibbs' laboratory. (*Silliman's Amer. Journ.* (2,) *49*, 1870, 356.)

D. MENDELEJEFF: 138 (O = 16).

Mendelejeff first suggested raising the atomic weight of cerium from 92 to 138. His reasons were a specific heat determination which he had made with very impure metal, and the fact that the supposed sesquioxide had never been shown to exist. He believes that the atomic weight will be found somewhat below 138, because that is the atomic weight of barium. (*Liebig's Annal.*, suppl., *8*, 1871, 186.)

H. BUEHRIG: *140.648* (O = 16).

Determined from ten analyses of the hydrous oxalate performed by combustion in a current of pure oxygen behind copper oxide. The water was collected in tubes filled with calcic chloride, and the carbonic acid in potash. Five experiments in which the cerium oxide was not determined gave a mean of 94.1304, on the supposition that cerous oxide contains 1 atom of oxygen and that O = 15.96, with an extreme difference of 0.0445. Five determinations in which the cerium was determined as ceric oxide gave 94.2260, with an extreme difference of 0.0431. Carbon was taken at 11.97. The mean result is Ce = 94.1782 for the above mentioned assumptions, [or 140.648 for O = 16, and on the supposition that cerous oxide is a sesqui-compound.] The oxalate was prepared from basic nitrate purified by Gibbs' method of oxidation with minium and nitric acid. The salt was spectroscopically pure. (*Erdmann's Journ. für Prak. Chem.*, *120*, 1873, 222.)

CHLORINE.

The density of chlorine gas and the specific heat of chlorine compounds leave no doubt that the atomic weight of this element is nearly 35.5. (*Gmelin-Kraut, l. c.*)

MARCET, BERZELIUS, WOLLASTON: *35.28* (O = 16).

Marcet, by experimenting on the calcination of pure marble, and on the saturation of chlorhydric acid with lime,

found as the mean of many trials, that 50.77 calcic carbonate are equivalent to 56.1 calcic chloride. Wollaston, taking the equivalent of calcic carbonate at 630, and that of calcium at 255, calculates the equivalent of chlorine at 441 for O = 100. Wollaston cites Berzelius as having obtained the same number by the conversion of plumbic carbonate into chloride. (*Phil. Trans.*, *97*, 1807, 301; *104*, 1814, 20.)

J. J. BERZELIUS: *35.412* (O = 16); 221.327 (O = 100).

The molecular weight of potassium chloride was ascertained from four experiments on the decomposition of potassium chlorate, which on being heated lost 39.15 per cent. oxygen. This gives for the chloride 932.567, (O = 100.) 100 parts of potassium chloride were further found equivalent to 192.4 parts argentic chloride, and 100 parts of silver to 132.75 argentic chloride. The value follows. Berzelius in his *Lehrbuch* accepts Marignac's determination and ascribes the error of the value he had obtained to the imperfect decomposition of that portion of the chlorate which was carried off as dust during the experiment. (*Poggend. Annal.*, *8*, 1826, 17; also *Lehrbuch der Chemie*, *3*, 1189, 1191.)

E. TURNER: 35.42 (O = 16).

Turner made two experiments on the decomposition of plumbic chloride with argentic nitrate. Assuming the atomic weight of lead at 103.6, and that 100 silver = 132.8 chloride, these analyses gave Cl = 35.43 and 35.48. Turner also decomposed corrosive sublimate with calcic oxide neutralized with nitric acid and precipitated with argentic nitrate. If mercury = 201, these analyses give a maximum of 35.28, and a minimum of 35.21, of which Turner selects the largest. From calomel treated in the same way, he arrived at the value 35.35. From his experiments on the composition of argentic chloride (and apparently comparison with potassic chloride and chlorate) Turner got 35.45. The mean of the other experiments was 35.35, but Turner considers 35.42 as being the most likely value. The plumbum chloride was prepared from the carbonate, and was purified by recrystallization, as was also the corrosive sublimate. The calomel was "prepared by Mr. Howard," and retained traces of moisture at 300°, which would make the atomic weight derived from its analysis too small. The values are for vacuum. (*Phil. Trans.*, *123*, 1833, 529.)

F. PENNY: 35.454 (O = 16).

Six experiments on the conversion of silver into nitrate gave 100 Ag = 157.441 nitrate; extreme difference, 0.028. Twelve experiments by three different methods on the conversion of silver into chloride gave 100 Ag = 132.837 chloride. Four series of experiments on the interconversion of potassic chloride, chlorate and nitrate gave for the difference between the molecular weights of the chloride and the nitrate 26.56. Corresponding experiments with sodium salts gave the same difference 26.568. The mean combined with the data for the silver salts gives the molecular weight of argentic chloride at 143.424, and Cl = 35.454. For further details see Penny's determinations of potassium, sodium, nitrogen and silver. The weighings were calculated for vacuum. (*Phil. Trans.*, *129*, 1839, 32.*)

R. PHILLIPS: 35.688 (O = 16).

In order to avoid the error possibly incurred by the melting of argentic chloride, etc., Phillips mixed known and nearly equivalent quantities of silver dissolved in nitric acid, or of crystallized argentic nitrate, with ammonium chloride; filtered, washed, and precipitated the comparatively minute amount of chlorine in the filtrate with silver solution. The fusion of this small quantity could cause no loss of importance. Phillips confesses that his ammonium chloride was acid and the only conclusions he draws are that Cl = 36, N = 14, O = 8 and H = 1 may be taken without considerable error if silver is 108. [The method seems to have been original and is nearly that afterwards adopted by Pelouze. The acidity of the ammonium chloride would of course give Cl too high.] (*Phil. Trans.*, *129*, 1839, 35.)

C. MARIGNAC: *36.001* (O = 16); 225.007 (O = 100).

Determined by passing chlorhydric acid gas over hot cupric oxide and condensing the water formed. The mean of three experiments was Cl = 450.013; the extreme difference is 0.2 for O = 100. The gas was made from recrys-

* This is one of the most elegant investigations of the kind to be found in chemical literature, though it scarcely receives a mention except from Stas, who accords to it the praise it deserves. Stas' wonderfully exhaustive researches were necessary to prove beyond question that chemistry has a mathematical basis, and that the atomic weights of the elements are incommensurate. Penny's investigation, taken in connection with Stas', shows that the highest degree of accuracy is not incompatible with the simplest means when they are applied with the care and acumen, without which exact results cannot, under any circumstances, be obtained.

tallized sea-salt and concentrated sulphuric acid and was dried by passing through nine tubes filled with sulphuric acid and pummice stone and with calcium chloride. The water was collected in a condenser to which drying tubes were appended. (*Paris Comptes Rendus*, *14*, 1842, 570.)

A. LAURENT: 35.468 (O = 16); 221.672 (O = 100).

Determined by three analyses of chloronaphthalintetrachloride, which he found to contain 58.22; 58.29; 58.28; per cent. Cl. The mean is 58.27 from which the value follows. (*Paris Comptes Rendus*, *14*, 1842, 456.)

According to Maumené, Laurent confessed that his salt was impure, containing chlorose compounds, in Gerhardt's *Comptes Rendus*, 1845, 108. (*Annal. de Chimie et de Physique*, (3,) *18*, 1846, 45.)

C. MARIGNAC: *35.37* (O =16); 221.07 (O = 100).

One synthesis of argentic chloride showed that 100 silver equals 32.74 chlorine. Berzelius had found 32.75, which Marignac adopts. Marignac found by six experiments on the decomposition of potassic chlorate by heat, that the molecular weight of potassic chloride was 932.14. He tested the equivalence of potassic and argentic chlorides by precipitating the former with argentic nitrate, filtering without the use of paper through a funnel with a capillary neck. The precipitate was dried and weighed, then melted and reweighed, no loss being observable. 100 potassium chloride gave 192.33 and 192.34 argentic chloride in two experiments, or reduced to vacuum, 192.26. Hence the atomic weight is 442.13. The potassic chloride was prepared by heating chlorate which had been purified by repeated recrystallizations. (*Liebig's Annal.*, *44*, 1842, 23.)

C. MARIGNAC: *35.456* (O = 16); 221.6 (O = 100).

In accordance with Pelouze's suggestion, Marignac repeated his determination of the composition of argentic chloride and of the equivalence of potassic and argentic chlorides, retaining the molecular weight of potassic chloride mentioned in the last paragraph. That value was obtained from the mean of six experiments on the decomposition of the chlorate which gave the percentage of oxygen at from 39.155 to 39.167; mean 39.161. Pelouze had got, as the mean of three experiments, 39.157. (*Paris Comptes Rendus*, *15*, 1842, 959.) Marignac made eleven experiments on the equivalence of silver and potassium chloride by Pelouze's

method, a known weight of silver being dissolved in nitric acid and added to a known and nearly equivalent amount of potassic chloride in solution, after which the excess was titrated with decimal standard solution. 100 parts of silver were precipitated by from 69.049 to 69.067, in mean by 69.062 chloride. 100 parts of chloride were precipitated by from 192.33 to 192.37, in mean by 192.348 silver. Five experiments were made on the composition of argentic chloride by dissolving silver in nitric acid, with precautions against loss by spirting, precipitation with chlorhydric acid, washing, drying, melting and weighing in the same vessel. 100 parts of silver gave from 132.825 to 132.844 chloride, mean 132.84. Calculation from these data gives *in vacuo* Ag = 1349.01; K = 488.94; Cl = 443.20; for O = 100 [or Ag = 107.921; K = 39.115; Cl = 35.456, for O = 16.] (*Berzelius' Jahresbericht*, *24*, 1844, 58; *Bibl. Univ.*, *46*, 1843, 350.)

C. Gerhardt: 36 (O = 16).

By heating potassic chlorate in a current of oxygen Gerhardt got, when he took precautions against loss by spirting, a mean of 60.949 chloride, from which he deduces 36 for chlorine without giving further data. (*Paris Comptes Rendus*, *21*, 1845, 1280.) Marignac shows that no data have ever been published which, in connection with Gerhardt's experiments, would give this value for chlorine. He adds further experiments of his own which, without aiming to establish more exactly the true atomic weight, prove it less than 36 (*Liebig's Annal.*, *59*, 1846, 284; *Bibl. Univ.*, *Arch. des Sciences*, *1*, 1846.)

E. J. Maumené: *35.462* (O = 16).

Maumené made seven analyses of argentic chloride by reduction in a current of pure hydrogen. Five of these experiments were made with quantities less than 10 grammes, and gave a mean of 100 silver = 32.736 Cl. Two experiments were made with about 30 grammes each, and gave 100 silver equal to 32.86 and 32.853 chlorine. Maumené prefers the latter, and deduces from them for chlorine the value 443.67 or *35.494* taking silver according to his own experiments at 1350.32. [If silver is taken at 107.93 (Stas) the same analyses give 35.462.] (*Annal. de Chimie et de Physique.* (3,) *18*, 1846, 41.)

A. LAURENT: 35.5 (O = 16); 221.88 (O = 100).

A single experiment was made as follows: pure silver was weighed off and placed in a matrass, nitric and chlorhydric acids were added, the liquid was evaporated and the chloride melted. An empty test was carried on at the same time to act as tare. Silver was taken at 1350. (*Paris Comptes Rendus*, *20*, 1849, 5.)

J. DUMAS: 35.5 (O = 16).

Determined by chloridizing different weights of pure silver by heating the metal in a current of chlorine. Experiments on 10 grammes and 20 grammes gave a mean of 35.5055, the difference being 0.013, for chlorine, if silver is 108. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 135.)

J. S. STAS: 35.457 (O = 16).

Stas found the atomic weight of chlorine by three independent methods:

(1.) From analysis of argentic chlorate and synthesis of argentic chloride. A known weight of the chlorate was dissolved in water, precipitated with sulphuric acid to secure advantageous division of the salt, and reduced while in suspension by a slow stream of sulphurous anhydride. The chloride was washed, dried, and weighed in the flask in which it was produced. The minute amount of chloride present in the chlorate was collected and taken into consideration, and the wash-water was carefully examined for silver. Two analyses (of about 140 and 260 grammes) gave for the molecular weight of the chloride 143.383 and 143.407, mean 143.395. A variety of syntheses of argentic chloride in the wet and in the dry way showed that 100 parts silver combined with nearly 32.850 parts chlorine. Stas assumes that none of his syntheses can possibly have given too much chloride and accepts the relation stated. These data give Cl = 35.458.

(2.) From the mutual relations of potassic chlorate and chloride and argentic chloride, combined with the composition of the last. The chlorate was decomposed either by gentle heat or in the wet way with chlorhydric acid. 100 parts of chlorate were found to contain 60.846 parts chloride as the mean of eight experiments; extreme difference, 0.012, which gives the molecular weight of potassic chloride at 74.59. The relation between potassic and argentic chloride was ascertained by Pelouze's method, (see Marignac's

determination above.) Twenty experiments on quantities of 32 grammes, and less, of silver gave 100 parts Ag = 69.103 parts KCl; extreme difference, 0.008. These data combined with the composition of argentic chloride given above, indicate for chlorine 35.460.

(3.) The composition of argentic nitrate was determined, and the difference between the atomic weights of nitrogen and chlorine. In two experiments silver was dissolved in nitric acid, the solution evaporated to dryness, and the nitrate kept melted until there was no further loss of weight. The result obtained was that 100 silver = 157.484 nitrate; difference, 0.008. From series of experiments on the relation of the chlorides of potassium, sodium, lithium and silver to the nitrates, Stas found the difference between a chloride and a nitrate from 26.586 to 26.591; mean 26.588. These data show that the atomic weight of chlorine lies between 35.455 and 35.460, and confirm the mean of all the determinations of Penny, Marignac, and Stas, 35.457. The silver for this investigation was either distilled or compared with distilled silver; it was found impossible to reduce the amount of silica in the alkaline salts below 0.002 of one per cent., it was therefore determined and allowed for; every possible method of purification by recrystallization and otherwise was resorted to to ensure purity. The weighings are all reduced to vacuum. (*Stas, Unters. über Chem. Proport., Leipzig*, 1867.)

CHROMIUM.

The specific heat of chromium, as determined from that of the oxide by Kopp, Regnault, and Neumann, corresponds to an atomic heat of from 5.4 to 5.98, if the atomic weight is taken at 52.4. (*Gmelin-Kraut, l. c.*)

J. J. Berzelius: *56.29* (O = 16); 351.819 (O = 100).

100 parts of plumbic nitrate, on precipitation with potassic chromate, gave 98.772 parts plumbic chromate. The value follows for Pb = 1294.498, and N = 88.518. (*Poggend. Annal., 8*, 1826, 22.)

T. Thomson: *64* (O = 16); 400 (O = 100).

3.14 grains of metallic chromium, converted into chromic acid by heating with potash and nitre, gave a precipitate of 16.23 grains plumbic chromate. (*Phil. Trans., 117*, 1827, 159.)

E. PELIGOT: *52.48* (O = 16); 328 (O = 100).

Peligot reached this value by a careful carbon determination of chromous acetate, produced by precipitating a dilute solution of chromium protochloride with sodium acetate, C = 75. Peligot does not regard the experiment as definitive, the salt possessing but little stability. (*Annal. de Chimie et de Physique*, (3,) *12*, 1844, 527.)

N. J. BERLIN: *52.54* (O = 16); 328.39 (O = 100).

Five experiments were made on the decomposition of argentic chromate with chlorhydric acid and alcohol. The silver chloride was washed in the flask in which it was precipitated, treated with aqua regia, melted and weighed without removal. The decanted fluid and the wash-water were evaporated to dryness with excess of ammonia, treated with water and the chromium oxide filtered off, heated to redness and weighed. [Nothing is said of the recovery of any argentic chloride that might have been removed by the decantation.] The value taken is calculated from the comparison of the amounts of argentic chloride and of chromium oxide obtained, Ag = 1349.66; Cl = 443.28. The extreme difference is 1, for O = 100. The argentic chromate was prepared by adding nitrate to a solution of potassic chromate. (*Erdmann's Journ. für Prak. Chem.*, *38*, 1846, 145.)

V. A. JACQUELIN: *50.08* (O = 16); 313 (O = 100).

By washing and purifying violet chromium chloride, Jacquelain obtained a substance which he took to be the pure chloride and which was more soluble than the unpurified salt. He analysed it by melting with soda, and arrived at the above number. (*Liebig's Annal.*, *64*, 1847, 275; *Revue Scient.*, *14*, 198.)

A. MOBERG: *53.563* (O = 16); 334.769 (O = 100).

Moberg made twelve experiments on the decomposition of chromium salts by heat. In two cases the sulphate dried at a low red heat was decomposed by strong ignition in a platinum crucible; the results being, 335.65 and 335.29 for chromium. Ten experiments were made on the decomposition of ammonium-chromium-alum which had been dried in a pulverized state for a long time. These determinations gave from 333.965 to 335.739. The value taken is the mean. The alum employed was prepared from pure material, and was repeatedly recrystallized. S = 200; N = 87.5. (*Erdmann's Journ. für Prak. Chem.*, *43*, 1848, 115.)

J. LEFORT: *52.97* (O = 16).

Determined by fourteen experiments on the precipitation of barium with sulphuric acid from a nitric acid solution of barium chromate. The barium chromate was prepared by precipitating potassium chromate with barium nitrate and drying the precipitate at 250°. [If these analyses are calculated for barium = 137 and S = 32, they give 100 barium chromate = 60.244 barium oxide, extreme difference, 0.26, and the atomic weight as above. Lefort seems to have taken Ba = 136.72. Berlin points out the correction which I have verified.] (*Erdmann's Journ. für Prak. Chem.*, *51*, 1850, 261; *Journ. de Pharm. et de Chim.*, *18*, 27.)

R. WILDENSTEIN: *53.485* (O = 16).

Determined by thirty-two experiments on the precipitation of barium chloride, desiccated at a red heat, by pure, neutral potassic chromate. The mean of these analyses gave 100 barium chromate = 81.70 barium chloride; extreme difference 0.35. Wildenstein calculates 334.48 without giving the assumption for chlorine. [If Cl = 35.457; Ba = 137, the value follows.] (*Erdmann's Journ. für Prak. Chem.*, *59*, 1853, 28.)

F. KESSLER: 52.3 (O = 16).

Kessler reached this value by comparing the oxidizing action of potassic chromate with that of potassic chlorate on arsenious acid. Six experiments were made on the oxidizing power of the chromate and twelve on that of the chlorate by a method of titration. By combining the maximum of one with the minimum of the other series, Kessler finds the atomic weight of chromium between 25.93 and 26.40; in mean 26.15, K being = 39.12 and Cl = 35.45. Confirmatory experiments were made on the oxidation of ferrous chloride in the same way. These gave a mean of 26.1. (*Poggend. Annal.*, *113*, 1861, 137; *95*, 1855, 208.)

M. SIEWART: 52.094 (O = 16).

Determined from the amount of chlorine in sublimed violet chromium chloride. Siewart criticises Kessler's determination and deduces from the latter's data a value 25.02. (*Kopp's Jahresbericht*, *14*, 1861, 240; *Halle, Zeitschr. für die Gesammt. Naturwis.*, *17*, 530.)

Kessler points out that the number 25.02 is a misprint in the *Jahresbericht*, and that Siewart's paper ascribes to him the value 26.02. (*Poggend. Ann.*, *117*, 1862, 352.)

COBALT.

The atomic heat of cobalt as determined by Regnault is 6.27 if the atomic weight is assumed at 58.8. (*Gmelin-Kraut, l. c.*)

E. ROTHOFF: *58.98* (O = 16); 368.65 (O = 100).

269.2 parts of cobalt oxide converted into neutral cobaltous chloride and precipitated with argentic nitrate gave 1029.9 argentic chloride, according to Berzelius' report. (*Poggend. Annal.*, *8*, 1826, 185.) Berzelius recalculates this analysis for Cl = 221.64 and Ag = 1349.66, and gets the value taken. (*Berzelius' Lehrbuch*, *3*, 1220.)

R. SCHNEIDER: 60.006 (O = 16); 375.04 (O = 100).

Determined from four analyses of the oxalate. The carbon was determined as in organic analysis; the metal by heating a known weight of the salt first in a current of air, then in one of oxygen, and by reduction of the oxide in hydrogen. The mean of the four analyses gave cobalt at 30.003, with an extreme difference of 0.026 for C = 6. The oxalate was prepared by converting the chemically pure cobalt of commerce into roseo-cobaltic chloride, from which the metal was again reduced, then dissolved in chlorhydric acid and carbonate precipitated, which was digested with oxalic acid. (*Poggend. Annal.*, *101*, 1857, 398.)

Marignac objects to this determination that the oxalate, being insoluble, may very likely have retained portions of the carbonate which could not be removed by washing. (*Bibl. Univ.*, *Arch. des Sciences*, (2,) *1*, 1858, 372.)

Schneider answers that he obtained nearly identical results from lots prepared at different times, and that he believes that he has convinced himself that the oxalate contained no carbonate. (*Poggend. Annal.*, *107*, 1859, 610.)

Gibbs, reporting Schneider's determination, remarks: "Very numerous and carefully made analyses of the ammonium-cobalt bases, executed in my laboratory, indicate 29.5 as the true equivalent of cobalt." (*Silliman's Amer. Journ.*, (2,) *25*, 1858, 438.)

C. MARIGNAC: about 59 (O = 16).

Five experiments were made on the decomposition of cobalt sulphate by heat. This salt can be readily dried without decomposition, and the acid is completely driven off by heat, but the resulting protoxide contains a slight

excess of oxygen. In order to remove this excess it was melted under a known weight of an acid silicate of lead. The results for cobalt varied from 29.32 to 29.38. The sulphate was purified by recrystallization. Marignac also experimented on the chloride. The weight of this salt varies greatly with the moisture of the atmosphere when crystallized, and attempts to desiccate it usually result in the formation of some insoluble compound. Three analyses of chloride appearing to contain one molecule of water, and dried at 100°, performed by titration with silver solution, gave cobalt at 29.42 to 29.51. Five experiments were made in the same way on chloride either melted in a current of chlorine or of chlorhydric acid gas, or calcined with ammonium chloride. These determinations gave from 29.36 to 29.42. (*Bibl. Univ., Arch. des Sciences*, (2,) *1*, 1858, 374.) [Marignac, in another investigation in the same volume, takes Ag = 108; Cl = 35.5.]

J. Dumas: 59 (O = 16).

Determined by five experiments on the titration of cobalt chloride with silver. The mean result for cobalt was 29.542; extreme difference 0.09; Ag = 108; Cl = 35.5. The chloride was prepared by dissolving pure cobalt in aqua regia, evaporating in the presence of excess of chlorhydric acid and heating to redness in a current of chlorhydric acid gas. In two of the determinations cobalt from a different lot, which had been heated in a vacuum was employed. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 148.)

W. J. Russell: 58.74 (O = 16).

Determined by fifteen experiments on the reduction of cobalt oxide in hydrogen. The value is the mean; the extreme difference is 0.19. To obtain pure cobalt oxide Claudet's salt was prepared, purified by recrystallization, etc., reduced in hydrogen, the metal dissolved in nitric acid and the resulting salt decomposed by heating in a stream of carbon di-oxide. (*Chem. Soc. Journ.*, (2,) *1*, 1863, 57.)

Schneider considers that no sufficient precautions were taken to exclude air in these experiments, and that higher oxides were formed. (*Poggend. Annal.*, *130*, 1867, 310.)

E. von Sommaruga: 60 (O = 16).

Determined by seven experiments on the reduction of purpureocobaltic chloride in a current of hydrogen. The mean of the experiments is 29.965; four of them give a

mean 29.996. The extreme difference is 0.093. The salt was prepared by solution of the carbonate in chlorhydric acid, addition of ammonia in excess, exposure to the air, washing of the precipitate with acidulated, then with pure water and drying at 110°. A special examination showed it free from other metals. Sommaruga took Cl = 35.5; N = 14. (*Erdmann's Journ. für Prak. Chem.*, *100*, 1867, 113; *Sitz.-Bericht der k. k. Akad.*, 1866.)

C. WINKLER: 59 (O = 16).

This value is derived from the mean of five experiments on the precipitation of gold from a solution of neutral crystallized chloride of gold and sodium. The metallic cobalt employed was prepared by the reduction of purpureo-cobaltic chloride. The latter was made from oxide, and was purified by recrystallization. Gold was assumed at 196. The mean of the results was 29.496; extreme difference, 0.071. (*Fresenius' Zeitschr. für Anal. Chem.*, *6*, 1867, 22.)

P. WELESKY: 58.98 (O = 16).

Determined from the analysis of cobalti-cyanides, performed by drying the salt at 100°, and heating to redness, first in a current of oxygen then of hydrogen. Four experiments with phenylammonium-cobalti-cyanide gave cobalt at from 29.38 to 29.59. Two experiments with ammonium-cobalti-cyanide gave from 29.46 to 29.55. Mean, 29.48; extreme difference, 0.21. A single experiment by Winkler's method gave 29.42. (*Berlin, Bericht der Chem. Ges.*, *2*, 1869, 592.)

W. J. RUSSEL: 58.76 (O = 16).

Determined by the amount of hydrogen set free by the solution of cobalt in hydrochloric acid. The value is the mean of 2 (or 4?) trials. The cobalt employed was that reduced by Russel in his former experiments on the same atomic weight. (*Chem. News*, *20*, 1869, 20.)

R. H. LEE: 59.10 (O = 16).

Determined by analysis of cobalti-cyanide salts. They were decomposed in a crucible by heating from above. The carbon separated was burned off in air and then in oxygen, and the metallic oxide reduced in hydrogen. Six experiments on the strychnine salt gave a mean of 59.05. Six experiments on the brucine salt gave 59.15. Six experi-

ments, made with especial care, on the reduction of purpureo-cobaltic chloride by hydrogen gave 59.09. (Reported by Gibbs. *Berlin, Bericht der Chem. Ges.*, *4*, 1871, 789.)

COPPER.

Regnault, Kopp, and others have determined the specific heat of copper. It corresponds to an atomic heat of about 6 if the atomic weight is taken at 63.3. (*Gmelin-Kraut, l. c.*)

R. CHENEVIX: F. H. WOLLASTON: *64* (O = 16); 400 (O = 100.)

Chenevix found 20 parts of oxygen equivalent to 100 parts of copper, whence Wollaston deduces the atomic weight. (*Phil. Trans.*, *104*, 1814, 21.)

J. J. BERZELIUS: *63.296* (O = 16); 395.6 (O = 100).

Determined by two experiments on the reduction of cupric oxide with hydrogen, which gave 395.695 and 395.507. The water was not weighed. (*Poggend. Annal.*, *8*, 1826, 182; and *Lehrbuch*, *3*, 1216.)

ERDMANN and MARCHAND: 63.456 (O = 16); 396.6 (O = 100.)

Determined by four experiments on the reduction of large quantities of cupric oxide in a current of hydrogen. The hydrogen was displaced by air after the completion of the reduction. The weight of the oxide and of the copper were reduced to vacuum, but not that of the weights employed. To obtain pure cupric oxide, pure vitrol was prepared and electrolytically decomposed. The copper thus obtained was dissolved in nitric acid, and the nitrate decomposed by heat. The value is the mean; the extreme difference is 0.056 for O = 8, or 0.112 for O = 16. (*Erdm. Journ. für Prak. Chem.*, *31*, 1844, 389.)

Berzelius points out that these analyses vary among themselves much more than his own. He makes the difference somewhat greater than it really is by neglecting the reduction to vacuum. (*Ibid.*, *37*, 1846, 72.)

Hampe shows that these analyses, correctly calculated, give Cu = 63.46. (*Zeitschr. für Berg Hütten-und-Sal-Wesen im Preus. St.*, *21*, 1873, 261.)

J. DUMAS: 63.5 (O = 16).

Dumas says that experiments on the reduction of cupric oxide and on the sulphidation of copper have shown him that the atomic weight of copper lies between 31.5 and 32, near 31.75, but that his experiments cannot be regarded as decisive. (*Annal. de Chimie et de Physique*, (3,) *55*, 1859, 129.)

MILLON and COMMAILLE: 63.128 (O = 16); 394.55 (O = 100).

These (three) experiments were in most respects a repetition of Erdmann and Marchand's. The value is the mean; the extreme difference is 0.49 for O = 100, or 0.0784 for O = 16. The sulphate was prepared free from iron or zinc by dissolving copper in ammoniacal sulphate or nitrate. The oxide was obtained by heating the nitrate. (*Paris Comptes Rendus*, *56*, 1863, 1249; and *57*, 1863, 145.)

Fresenius sees no reason for preferring this to Erdmann and Marchand's value. (*Fresenius' Zeitschr. für Anal. Chem.*, *2*, 1863, 474.)

W. HAMPE: 63.3296 (O = 16).

In three experiments cupric oxide was reduced in a current of hydrogen with all possible precautions. The hydrogen was displaced by air before weighing, though it was shown by experiment that porous copper does not condense hydrogen. The metal was heated till incipient melting was observed. The reduction and melting were repeated without altering the weight. Hampe attempted to control his results by reconverting the metal into oxide, but was unable to effect complete oxidation. The water produced by the reduction was found to be perfectly pure. The mean result was Cu = 31.6696, maximum, 31.6729, minimum, 31.6648. The oxide was prepared from metallic copper. To obtain pure metallic copper, sulphate free from bismuth was electrolytically decomposed, the finely divided metal well washed, then melted, first in a current of carbon di-oxide, afterwards in hydrogen, and then again in carbon di-oxide. From the metal, basic nitrate was formed and from this salt, by heating first in air and then in oxygen, oxide. In two experiments the atomic weight of copper was determined by decomposing cupric sulphate by electrolysis, and weighing the metal. The residual fluid was evaporated, and a minute amount of copper, which had escaped decomposition, was

recovered and determined as sulphide. For S = 16.037 and O = 8, these experiments gave Cu = 31.6577 and 31.66. The value taken is the mean of the two series. All weighings were reduced to vacuum. (*Zeitschr. für Berg Hütten- und Sal.-Wesen im Preus. St.*, *21*, 1873, 260.)

DIDYMIUM.

W. F. Hillebrand found the specific heat of this metal 0.04563, which corresponds to an atomic heat of 6.60 for an atomic weight of 144.78. (*Poggend. Annal.*, *158*, 1876, 78.)

C. Marignac: *148.8* (O = 16); *930* (O = 100).

Determined by decomposing disulphate with barium chloride. Assuming the lower oxide as a prot-oxide, he calculated the atomic weight at 620. As Marignac was not confident of the purity of his salt, and subsequently became certain that the method was untrustworthy, details are unnecessary. (*Liebig's Annal.*, *71*, 1849, 313.)

C. Marignac: *143.81* (O = 16); *898.8* (O = 100).

Five experiments were made on the sulphate by decomposition with ammonium oxalate. The didymium oxalate was heated to redness, and the resulting oxide weighed. On the assumption that the oxide was protoxide, these determinations gave a mean of 598.2 for Di, with an extreme difference of 2.5. Three experiments were made on the chloride, the insoluble oxychloride, which is unavoidable in drying the salt, being separated. The chlorine was determined with silver, and the Di as in the previous experiments. These determinations gave Di at 600.2, with an extreme difference of 5.2 for Cl = 443.2 and S = 200. The salts were prepared from cerite. The cerium was extracted by treatment at first with dilute and afterwards with concentrated nitric acid. The sulphates of Di and La were separated by partial precipitation with oxalic acid and by partial recrystallization. (*Annal. de Chimie et de Phys.*, (3,) *38*, 1853, 148.)

R. Hermann: *142.44* (O = 16); *890.25* (O = 100).

In one experiment sulphate which had been heated to a low red heat, was dissolved, decomposed with ammonium

oxalate, the precipitate incinerated and the oxide weighed. The result was Di = 594.46, on the prot-oxide hypothesis, for S = 200. In one experiment the chloride was decomposed with argentic nitrate, oxychloride being filtered off and allowed for, and the argentic chloride weighed. This experiment gave Di = 592.54 for Cl = 443.2. For the preparation of the salt see Lanthanium. (*Erdmann's Journ. für Prak. Chem.*, *82*, 1861, 387.)

H. ZSCHIESCHE: About *144* (O = 16).

In five experiments the sulphate was exposed to a white heat until the weight became constant and the oxide on being tested showed no traces of sulphur. The results varied from Di = 46.585 to 48.08, probably, Zschiesche thinks, on account of the presence of La. S =16. Di was separated from La by the partial precipitation of the nitrates with oxalic acid, the first portion falling being redissolved, and the partial precipitation repeated twenty times. (*Erdmann's Journ. für Prak. Chem.*, *107*, 1869, 74.

C. ERK: *142.695* (O = 16).

The sulphate was decomposed with ammonium oxalate, the oxalate incinerated and the oxide weighed. The sulphuric acid was also precipitated as barium salt, and weighed. Three experiments gave a mean of Di = 95.13, on the prot-oxide hypothesis, with an extreme difference of 0.78. The Di salt was found to contain yttrium which was removed by repeated fractional precipitation with sodium sulphate. This re-agent precipitates a double salt of Di and sodium. The purification was continued until the atomic weight became constant. (*Kopp's Jahresbericht*, 1870, 319, *Jena'sche Zeitschr, für Med. und Nat.*, *6*, 299.)

Casselmann thinks that the salt may still have retained yttrium, and Fresenius objects to the barium sulphate determination on the well-known grounds. (*Fresenius' Zeitschr*, *10*, 510.)

D. MENDELEJEFF: 138 (O = 16).

From the analogy between Di and cerium and other elements, and from the fact that it forms two oxides, Mendelejeff believes that its lower oxide is a sesqui-oxide, and its atomic weight 138. Mendelejeff points out that an error is to be apprehended in the received values from the fact that we have no guarantee of the pureness of Di salts except recrystallization. (*Liebig's Annal. Suppl. 8*, 1871, 190.)

P. T. CLEVE: 147.01 (O = 16).

Determined by the conversion of didymium oxide into sulphate. The number is the mean of six experiments; extreme difference 0.58. The Di was separated from lanthanium by repeated precipitations of basic nitrate from nitric acid solution, conversion into formate and decomposition of this salt by heat. (*Kopp's Jahresbericht*, 1874, 259. *Bulletin Soc. Chimique*, (2,) *21*, 246.)

W. F. HILLEBRAND: 144.78 (O = 16).

Determined by one experiment on the conversion of metallic Di into nitrate, and then, by heat, into oxide. The impurities were determined. The metal was reduced electrolytically from the chloride. (*Poggend. Annal.*, *158*, 1876, 78.)

ERBIUM.

The physical and chemical analogies of the salts of this element have led Mendelejeff (*Liebig's Annal.*, *Suppl. 8*, 1871, 195,) and P. T. Cleve (*Kopp's Jahresbericht*, 1874, 260; *Bulletin Soc. Chimique*, (2,) *21*, 344,) to regard it as triatomic, and its atomic weight as about 170.

M. DELAFONTAINE: *113.04* (O = 16).

M. Delafontaine investigated gadolinite by Mosander's method, and obtained besides yttrium, two substances which he regarded as erbium and terbium. From the sulphates, in which he supposed the metals to exist as protoxides, he determined erbium at 496 and terbium at 471 for O = 100. Popp (*Liebig's Annalen*, *131*, 189,) and Bunsen and Bahr (*Ibid*, *137*, 1,) have shown that Mosander's method gives only mixtures. Delafontaine's terbium is thought to have been chiefly the erbium of other chemists. (*Liebig's Annal.*, *134*, 1865, 108.)

BAHR and BUNSEN: *168.9* (O = 16).

A known weight of erbium oxide was treated with a very slightly excessive quantity of sulphuric acid; the solution evaporated and the excess of acid driven off at as low a temperature as possible. The increase of weight indicates 112.6 for S = 32. The oxide was prepared from gadoli-

nite. The mineral was decomposed with chlorhydric acid, and the earths precipitated with oxalic acid. The oxalates were converted into nitrates, the cerium metals separated with potassic sulphate, and calcium and magnesium with ammonia. If the nitrates of yttrium and erbium are dissolved in boiling water, basic erbium nitrate with some yttrium crystallizes out, leaving yttrium nitrate with some erbium in solution. The process of partial crystallization was continued as long as the atomic weight of the erbium salt continued increasing. Bahr and Bunsen believe, however, that the atomic weight may be some hundredths higher. The salt was spectroscopically free from didymium. (*Liebig's Annal.*, *137*, 1866, 2.)

P. T. CLEVE and O. M. HOEGLUND: *170.55* (O = 16).

Determined from four syntheses of the sulphate, giving 113.7 on the diatomic hypothesis. The oxide was purified by heating the nitrates, etc., according to Berlin. (*Blomstrand* in *Berlin, Ber. der Chem. Ges.*, 1873, 1467; *Bull. Soc. Chimique*, 1873, 193 and 289.)

FLUORINE.

Dumas and Peligot and others have determined the vapor-density of a number of fluorine compounds. They correspond to an atomic weight of about 19. (*L. Meyer*, *l. c.*)

H. DAVY: *18.86* (O = 16).

Determined by the conversion of Derbyshire spar into sulphate. 100 parts of spar gave a maximum of 175.2 parts calcic sulphate. [If S = 32; Ca = 40; the value follows.] (*Phil. Trans.*, *104*, 1814, 64.)

J. J. BERZELIUS: *18.85* (O = 16).

Determined by conversion of calcic fluoride into sulphate. 100 parts fluoride gave, in mean of three experiments, 175 parts sulphate; extreme difference, 0.2. [If S = 32; Ca = 40; the value follows.] (*Poggend. Annal.*, *8*, 1826, 18, and *Lehrbuch*, *3*, 1196.)

P. LOUYET: 19 (O = 16).

Determined by six experiments on the conversion of fluorspar into calcic sulphate. The mean result was 100 parts spar equal 174.36 sulphate, with an extreme difference of 0.3. Spar from Derbyshire was pulverized, digested with chlorhydric acid, and the foreign matter removed by lutration in water. It was completely dissolved in sulphuric acid, the excess of which was driven off by heat continued till a constant weight was obtained. S = 200; Ca = 250. (*Erdmann's Journ. für Prak. Chem.*, *47*, 1849, 104; *Annal. de Chim. et de Phys.*, (3,) *25*, 1849, 291.)

E. FREMY.

This chemist says that his analyses essentially confirm Berzelius' determination. (*Annal. de Chimie et de Phys.*, (3,) *47*, 1856, 27.)

J. DUMAS: 19 (O = 16).

Determined by the conversion of fluorides into sulphates. A single experiment on the conversion of calcic fluoride gave 18.96; two experiments on sodic fluoride, 19.06; and two on potassic fluoride, 18.99. The mean is 19.01; extreme difference, 0.12. Ca = 20; Na = 23; K = 39; S = 16. The alkaline salts were well crystallized and were fused before use. (*Annal. de Chim. et de Phys.*, (3,) *55*, 170.)

S. DE LUCCA: 18.96 (O = 16).

Determined by four experiments on the conversion of a pure spar from Gerfalco into sulphate. The extreme difference was 0.15. The decomposition was very difficult. The loss on ignition and the residue left on evaporation of the acid employed were taken into consideration. [S apparently = 16; Ca = 20.] (*Paris Comptes Rendus*, *51*, 1860, 299.)

GALLIUM.

Berthelot has determined the specific heat of gallium at 0.079 corresponding to an atomic heat of 5.52, if the atomic weight is 69.9. (*Paris Comptes Rend.*, *86*, 1878, 786.)

L. DE BOISBAUDRAN: 69.9 (O = 16).

This chemist "has prepared several chlorides, [*samples* of chloride?] several bromides, and several anhydrous iodides of gallium. He has determined the atomic weight of gallium, and found it 69.9, (mean of two experiments.)" (*Paris Comptes Rend.*, *86*, 1878, 756.)

GOLD.

Dulong and Petit and Regnault have determined the specific heat of gold. It corresponds to an atomic weight of about 200. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *196.4* (O = 16).

Determined by the amount of mercury necessary to precipitate a known weight of gold from solution of chloride. 142.9 mercury were found equivalent to 93.55 gold. [If Hg = 200, this gives Au = 196.397.] (*Poggend. Annal.*, *8*, 1826, 178.)

T. THOMSON: 200 (O = 16).

This value is derived from a somewhat inaccurate experiment on the reduction of auric chloride by ferrous sulphate. (*Edinb. Trans. Roy. Soc.*, *11*, 1831, 26.)

J. J. BERZELIUS: *196.73* (O = 16).

Determined by five experiments on the relative amount of gold and of potassic chloride in the residue obtained by heating the double chloride of the two metals in an atmosphere of hydrogen. [Calculated for KCl = 74.594, (Stas,) these experiments give a maximum of 196.79, minimum of 196.63 and a mean of 196.727. The atomic weight derived from the first experiment is misprinted in the Lehrbuch, as is the mean in the Jahresbericht.] (*Berzelius' Jahresbericht*, *25*, 1846, 41; and *Lehrbuch*, *3*, 1845, 1212.)

A. LEVOL: *196.26* (O = 16).

A known weight of gold was converted into chloride, and this salt decomposed in boiling solution by a current of pure, washed sulphurous acid. The sulphuric acid formed

was precipitated as barium salt, and the atomic weight calculated by comparison of the gold employed and the barium sulphate obtained. 1000 gold gave 1782 sulphate. [If the atomic weight of S = 32.0742, and that of Ba = 137.08, the above value follows.] (*Annal. de Chimie et de Phys.*, (3,) *30*, 1850, 355.)

HYDROGEN.

The density of hydrogen as determined by a great number of investigators, especially Regnault, is about $\frac{1}{16}$ of that of oxygen. If oxygen is 16, the atomic weight of hydrogen is consequently about 1.

The atomic weights of the elements are compared either with that of oxygen or with that of hydrogen. The main advantage of assuming hydrogen as unity is the simplicity of the approximate values expressed in terms of the atomic weight of this element. The hypothesis of Prout has also had much influence in giving currency to this unit. The advantages of oxygen as a standard of comparison consist in the fact that it combines with all the elements, except fluorine, and in the superior accuracy of the determination of its specific gravity. The percentage variation between Regnault's determinations of the specific gravity of hydrogen was thirty-six times as great as occurred in his experiments on oxygen. Unnecessary complication in the approximate values of the atomic weights is as well avoided by assuming oxygen at 16 as by taking hydrogen at 1.

These reasons for the adoption of the atomic weight of oxygen as a standard of comparison appear to me conclusive, and accordingly all values in this paper have been reduced to O = 16.

F. H. Wollaston: *1.06* (O = 16); 6.64 (O = 100).

Gay-Lussac and Humboldt having shown that two volumes of hydrogen and one of oxygen form water, and Biot and Arago having determined the specific gravity of these gases, Wollaston calculated the above atomic weight. (*Phil. Trans.*, *104*, 1814, 20.)

Berzelius and Dulong: *0.9984* (O = 16); 6.24 (O = 100).

Determined by three experiments on the reduction of cupric oxide by hydrogen. The hydrogen was made from

pure materials, and passed through a solution of litharge in potash, and over a coarse powder of caustic potash before use. The resultant water was caught in calcic chloride and weighed. The determination was also confirmed by experiments on the specific gravity of oxygen and hydrogen. The minimum result for hydrogen was 0.9934, the maximum 1.0086. (*Thomson's Annals of Phil.*, *2*, 1821, 48.)

T. THOMSON: *1* (O = 16); 6.25 (O =100).

Thomson found the Sp. Gr. of H = 0.0694. Taking that of O as 1.1111 on theoretical grounds (the supposed compound nature of air, etc.,) he calculates the above value. (*Erdmann's Journ. für Prak. Chem.*, *8*, 1836, 374; *Records of Gen. Sci.*, *R. D. Thomson*, 1836, 179.)

J. DUMAS: *1.0012* (O = 16); 6.2575 (O = 100).

Determined by nineteen experiments on the reduction of cupric oxide with pure hydrogen. The gas was made from pure materials and was passed through solutions of plumbic nitrate and argentic sulphate, and over potash, and dried with cold sulphuric acid or with phosphoric acid. The weighings of the oxide and of the reduced copper were made *in vacuo*. [Dumas corrected the results obtained for the air contained in the sulphuric acid, but does not explain how he estimated it, while certain other possible corrections are not mentioned.] The mean of the corrected results is 12.515. The extreme difference is 0.09 for O = 100. Without the correction for absorbed air the mean is 12.533, [or 1.00264]; maximum 12.583; minimum 12.481. (*Paris Comptes Rend.*, *14*, 1842, 537.)

ERDMANN and MARCHAND: *1.0016* (O = 16); 6.26 (O = 100).

Determined by eight experiments on the reduction of cupric oxide with hydrogen, the number is the mean of the results. In four of the experiments the correction for vacuum was calculated. These gave H = 12.548; extreme difference, 0.067. In four experiments the weighings were made *in vacuo*. These gave a mean of 12.492, with an extreme difference of 0.015. The oxide employed was either copper scale or was produced from cupric nitrate. The hydrogen was made from pure zinc and sulphuric acid, and was purified with potash in solution and in lumps, mercuric chloride, sulphuric acid, and chloride of calcium. In the

last five experiments the gas was also passed over red-hot copper to remove traces of oxygen.) (*Erdmann's Journ. für Prak. Chem.*, *26*, 1842, 461.)

J. S. Stas: 1.0025 (O = 16).

From all the investigations that have been made on the specific gravity of the gases, the composition of water, etc., Stas is inclined to believe that the atomic weight of hydrogen cannot be less than above. Stas found that 100 silver were equivalent to 49.5973 ammonium chloride. [If N = 14.044, and Cl = 35.457, this relation would give H = 1.0074.] (*Stas, Untersuch. über. Chem. Prop.*, *Leipzig*, 1867.)

J. Thomsen: *1.0025* (O = 16).

Thomsen made three experiments on the oxidation of a known volume of hydrogen by cupric oxide, and five experiments on the combustion of a known volume of hydrogen in oxygen, which proved that 2 litres of hydrogen gave 1.6082 grammes of water under normal conditions, and at latitude 45°. According to Regnault, 1 litre of oxygen and 2 litres of hydrogen would weigh 1.6084 grammes. Hence 1 volume oxygen and 2 volumes hydrogen form water; and if H = 1, O = 15.96, [or if O = 16, H = 1.0025.] (*Berlin, Ber. der Chem. Ges.*, *3*, 1870, 928.)

INDIUM.

Bunsen found the specific heat of In 0.565 and 0.574, which correspond to an atomic weight of about 114. (*Poggend. Annal.*, *141*, 28.)

F. Reich and T. Richter: *111.39* (O = 16).

In one experiment pure indium was dissolved in nitric acid, the oxide precipitated with ammonia and weighed. This experiment gave In = 463.4 for O = 100, and on the supposition that the metal was di-atomic. In a second experiment indium sulphide was dissolved in nitric acid, and the resulting sulphuric acid precipitated with barium chloride. This gave In = 464.9. The number taken is the mean. S = 200. The metal was prepared from the oxide. After the removal of lead, etc., with hydrogen sulphide, the oxides

of iron and indium were precipitated with ammonia, the precipitate dissolved in acetic acid and impure indium sulphide reprecipitated. This operation was repeated, and the last traces of iron were removed by partial precipitation with ammonia. (*Erdmann's Journ. für Prak. Chem.*, *92*, 1864, 484.)

C. WINKLER: *107.754* (O = 16).

Determined by decomposing the nitrate by heat, and weighing the resulting oxide. The mean result of three experiments was In = 35.918 for O = 8, and assuming the univalence of the metal. Extreme difference, 0.079. Metallic indium was prepared by solution of the impure sulphide in chlorhydric acid, precipitation of indium by barium carbonate, solution in sulphuric acid, and precipitation by ammonia of the oxide which was reduced by hydrogen. [This indium seems to have contained iron.] (*Erdmann's Journ. für Prak. Chem.*, *94*, 1865, 1.)

C. WINKLER: *113.439* (O = 16).

In two experiments the double chloride of gold and sodium was decomposed by pure indium, giving 37.73 and 37.80 for O = 8, and assuming univalence for the metal. In two experiments the nitrate was decomposed by heat, giving In = 37.845 and 37.879. In one experiment the oxide was precipitated from nitric acid solution by ammonia. This experiment gave In = 37.811. The number taken is the mean. The impure indium sulphide was purified as in Winkler's former determination with barium carbonate, but this process requires to be repeated several times. The reduction of the oxide was performed with sodium, the excess of which was removed from the regulus by cupellation in soda. (*Erdmann's Journ. für Prak. Chem.*, *102*, 1867, 282.)

R. BUNSEN: 113.76 (O = 16).

Determined by converting metallic indium into oxide by means of nitric acid and heat. He seems to regard the experiment only as confirmatory of Winkler's. The metal was the same which served for the determination of the specific heat, and was carefully tested for all impurities. (*Poggend. Annal.*, *141*, 1870, 28.)

IODINE.

Dumas determined the specific gravity of iodine vapor. It answers to an atomic weight of about 127. (*Annal. de Chim. et de Phys.*, *33*, 1826, 337.)

L. J. Gay-Lussac: *123.9* (O = 16).

100 parts of iodine were found equivalent to 26.225 parts of zinc. [If Zn = 65, these figures give the atomic weight at 123.9.] (*Poggend. Annal.*, *14*, 1828, 559; *Annal. de Chimie*, *91*, 1814, 5.)

W. Prout: *126* (O = 16).

Prout found 100 parts of iodine equivalent to 25.8 parts of zinc. [If Zn = 65, this gives I = 125.97.] (*Thomson's Annals of Phil.*, *6*, 1815, 323.)

T. Thomson: *124* (O = 16); 775 (O = 100).

Thomson found 20.5 potassic iodide = 19.75 zinc iodide, = 20.75 plumbic nitrate. [If K = 39.1, and plumbic nitrate = 331, the relation given leads to an atomic weight of 124.41.] Thomson thinks that his iodine may have been somewhat impure, as he purified it only by sublimation. (*Thomson's System of Chem.*, 7th ed., *1*, 1831, 81.)

J. Dumas: *126.13* (O = 16).

Dumas determined the density of iodine vapor at 8.716 for air = 1. [Referred to the molecular weight of oxygen, this density gives the above number for the atomic weight.] Dumas thinks it probable that it can be more accurately determined by analysis. (*Annal. de Chim. et de Phys.*, *33*, 1826, 337.)

J. J. Berzelius: *126.26* (O = 16); 789.14 (O = 100).

Determined by decomposing a known weight of argentic iodide in a current of chlorine, melting the chloride and expelling free chlorine by atmospheric air. The number is the mean of two experiments; difference, 0.01. Ag = 1351.607; Cl = 442.653. The iodide was prepared by precipitation from a solution of potassic iodide with argentic nitrate. The first portion of the precipitate was set aside as possibly contaminated with chlorine. (*Poggend. Ann.*, *14*, 1828, 562.)

C. MARIGNAC: 126.844 (O = 16).

In five experiments a known weight of silver was dissolved in nitric acid and precipitated by a known amount of potassic iodide according to Pelouze's modification of Gay-Lussac's method. The mean result was 100 Ag = 153.74 KI in air; extreme difference, 0.14. Stas has recalculated this result for Ag = 107.93, and K = 39.137. The atomic weight so found is, *in vacuo*, 126.847. In three experiments a known weight of silver was dissolved and precipitated as iodide; mean result, 100 Ag = 217.511 iodide. Extreme difference, 0.04. From these data Stas gets I = 126.84. The iodine was purified by recrystallization as potassic iodate. The methods employed by previous experimenters were ineffectual. (*Berzelius' Jahresbericht*, *24*, 75; *Bibl. Univ. de Genève*, *46*, 1842, 367; also, *Stas, Untersuch. über Chem. Prop.*, 153.)

E. MILLON: *126.07* (O = 16); 787.915 (O = 100).

Three experiments were made on the decomposition of potassic iodate. The mean loss of oxygen was 22.473 per cent; extreme difference, 0.03. If K = 488.94, this gives I = 1580.93. In three experiments argentic iodate, which had been dried for a long time at 200°, was employed, which lost 17.0467 per cent. oxygen; extreme difference, 0.03. If Ag = 1349.01, these data give I = 1570.73. [Berzelius cites this as an atomic weight determination; Millon, however, seems to have regarded it only as a confirmation of Berzelius' number.] Millon prepared pure iodine by passing a current of chlorine through a solution of KI till the precipitated I was redissolved, and reprecipitating with an excess of KI. (*Annal. de Chim. et de Phys.*, (3,) *9*, 1843, 407.)

V. A. JACQUELIN: 125.6 (O = 16); 785 (O = 100).

Determined by the analysis of iodic acid with silver. The acid was prepared by the oxidation of iodine with nitric acid of sp. gr. 1.5. The purity of the preparation does not seem to have been tested. Ag = 1351. (*Erdmann's Journ. für Prak. Chem.*, *51*, 1850, 458; *Annal. de Chim. et de Phys.*, (3,) *30*, 1850, 332.)

J. DUMAS: 127 (O = 16).

Determined by the conversion of argentic iodide into chloride in a current of dry chlorine. Two experiments gave 127.04 and 127.01 for Ag = 108; Cl = 35.5. In Gmelin-Kraut's *Handbuch* these data are recalculated for Ag =

107.93 and Cl = 35.457, giving I = 126.941 and 126.928. The argentic iodide used was prepared from zinc iodide which had been prepared from iodine in large crystals. The argentic iodide was fused. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 163.)

J. S. Stas: 126.851.

Stas ascertained the molecular weight of argentic iodide as follows:

In two complete analyses, a known weight of argentic iodate was decomposed by heat in a current of pure, dry nitrogen. The oxygen set free was caught by hot copper and weighed, as well as the residual argentic iodide. In one experiment argentic iodate was dissolved in ammonia, precipitated by sulphuric acid, (to secure advantageous division of the salt,) and reduced while in suspension by a slow current of sulphurous acid. The mean molecular weight reached was 234.779; extreme difference, 0.063. The samples of iodate employed were prepared: (1.) From argentic sulphate and potassic iodate, mixed boiling, the latter in excess, thorough washing and drying in air freed from organic particles; (2.) By the reaction of potassic iodate on argentic hyposulphite. The purity of the salt was carefully tested.

Stas ascertained the composition of argentic iodide as follows:

(1.) A known weight of argentic nitrate was precipitated by hydro-iodic acid and the argentic iodide washed, dried, and weighed in the same vessel. (2.) A known weight of Ag was dissolved in nitric acid, converted into sulphate, dissolved in very dilute sulphuric acid, and precipitated with hydro-iodic acid. The precipitate was washed at temperatures increasing up to 90°. (3.) A known weight of argentic sulphate was allowed to react on a known and nearly equivalent weight of iodine in an aqueous solution of sulphurous and sulphuric acids at 10°, and in the dark, till all the iodine was taken up. The excess of iodine was titrated with silver solution, and the iodide weighed. This method was employed in two experiments. (4) differed from (3) mainly in the conversion of the iodine into ammonium iodide before bringing it into contact with argentic sulphate. Four experiments were made by the last method.

The mean composition of the iodide, as derived from all the experiments, is 100 Ag = 117.5343 iodine. From these data Stas calculates the atomic weight of I at 126.857, and

that of silver at 107.928. [The sum of these weights is not the molecular weight, and this, as well as recalculation of the data, shows that the number is a misprint for 126.851. Stas' results are, therefore, even closer to Marignac's than his memoir would indicate.]

Most of the experiments were made with iodine prepared by the decomposition of nitric iodide decomposed in a large volume of water at 65°. The iodine was further purified by distillation over barium oxide and by other means. For the preparation of silver see that metal. All possible precautions were observed in the preparation of all reagents and in the conduct of the experiments. (*Stas, Untersuch. über Chem. Prop. Leipzig*, 1867.)

IRIDIUM.

Regnault determined the specific heat of iridium. It corresponds to an atomic weight of about 198. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *197.19* (O = 16).

Berzelius determined this value from analysis of potassium chloro-iridiate. This salt reduced in hydrogen lost 29 per cent., the same quantity lost by the corresponding platinum salt, (*vide* platinum.) Berzelius originally calculated the atomic weight of the platinum metals both from the loss of chlorine of these double salts and from the relation between the metal and the potassic chloride left after reduction. In his *Lehrbuch* he points out the impossibility of complete desiccation, and resorts exclusively to the latter method of calculation. With respect to iridium he merely asserts that its atomic weight is the same as that of platinum, without there, or elsewhere, giving data as to the amounts of iridium and potassic chloride found in the reduced salt. It is, therefore, open to question whether he assumed the identity from the loss on reduction or not. [If Pt = Ir, and if KCl = 74.594, the value follows; see platinum.] Osmium and iridium were separated by fusion with nitre, solution, and distillation. The residue was fused with potassic chloride and sodium carbonate. On solution the iridium remains behind. This residue was repeatedly roasted and reduced to drive off osmium compounds. The potassium chloro-iridiate was formed from the pure metal. (*Poggend. Ann.*, *13*, 1828, 468; *Kongl. Vet. Acad. Handl.*, 1828.)

C. E. CLAUS: W. M. WATTS: 197.6 (O = 16).

Watts recalculated two analyses of potassium chloroiridiate by Claus from the loss in reduction, and for Cl = 35.457, (Stas.) From one analysis he finds K = 39.87, and Ir = 198.56; from the other K = 39.93, and Ir = 196.62. (*Chem. News*, *19*, 1869, 302.)

IRON.

Regnault, Kopp and others have determined the specific heat of this metal. It corresponds to an atomic weight of about 56. (*Gmelin-Kraut*, *l. c.*)

L. J. THENARD: F. H. WOLLASTON: *55.2* (O = 16); 345 (O = 100).

Thenard determined the composition of the oxide at 22.5 O and 77.5 Fe, whence Wollaston calculates the value. (*Phil. Trans.*, *104*, 1814, 21.)

J. J. BERZELIUS: *54.27* (O = 16); 339.213 (O = 100).

Determined by repeated experiments on the oxidation of iron, such as is used for piano wire, with nitric acid. The carbon was determined and allowed for. Berzelius in his *Lehrbuch* shows that the error in this determination lay in the unsuspected presence of soluble silica and on reänalysis he found enough of it to correct the number when taken into account. (*Poggend. Ann.*, *8*, 1826, 185.)

G. MAGNUS: *54.25* (O = 16); *339.06* (O = 100).

Magnus' experiments were made by reducing ferric oxide in a current of hydrogen at about the temperature of boiling mercury. He regarded them simply as comfirmatory of Berzelius' number. (*Poggend. Ann.*, *3*, 1825, 84.)

F. STROMEYER: *55.6* (O = 16).

Determined by reducing ferric oxide at a red heat by hydrogen. The oxide is reduced only with great difficulty at a lower temperature. The mean of the experiments gave the oxygen contents at 30.15 per cent., [whence I have calculated the value.] (*Poggend. Ann.*, *6*, 1826, 475.)

that of silver at 107.928. [The sum of these weights is not the molecular weight, and this, as well as recalculation of the data, shows that the number is a misprint for 126.851. Stas' results are, therefore, even closer to Marignac's than his memoir would indicate.]

Most of the experiments were made with iodine prepared by the decomposition of nitric iodide decomposed in a large volume of water at 65°. The iodine was further purified by distillation over barium oxide and by other means. For the preparation of silver see that metal. All possible precautions were observed in the preparation of all reagents and in the conduct of the experiments. (*Stas, Untersuch. über Chem. Prop. Leipzig*, 1867.)

IRIDIUM.

Regnault determined the specific heat of iridium. It corresponds to an atomic weight of about 198. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *197.19* (O = 16).

Berzelius determined this value from analysis of potassium chloro-iridiate. This salt reduced in hydrogen lost 29 per cent., the same quantity lost by the corresponding platinum salt, (*vide* platinum.) Berzelius originally calculated the atomic weight of the platinum metals both from the loss of chlorine of these double salts and from the relation between the metal and the potassic chloride left after reduction. In his *Lehrbuch* he points out the impossibility of complete desiccation, and resorts exclusively to the latter method of calculation. With respect to iridium he merely asserts that its atomic weight is the same as that of platinum, without there, or elsewhere, giving data as to the amounts of iridium and potassic chloride found in the reduced salt. It is, therefore, open to question whether he assumed the identity from the loss on reduction or not. [If Pt = Ir, and if KCl = 74.594, the value follows; see platinum.] Osmium and iridium were separated by fusion with nitre, solution, and distillation. The residue was fused with potassic chloride and sodium carbonate. On solution the iridium remains behind. This residue was repeatedly roasted and reduced to drive off osmium compounds. The potassium chloro-iridiate was formed from the pure metal. (*Poggend. Ann.*, *13*, 1828, 468; *Kongl. Vet. Acad. Handl.*, 1828.)

C. E. CLAUS: W. M. WATTS: 197.6 (O = 16).

Watts recalculated two analyses of potassium chloroiridiate by Claus from the loss in reduction, and for Cl = 35.457, (Stas.) From one analysis he finds K = 39.87, and Ir = 198.56; from the other K = 39.93, and Ir = 196.62. (*Chem. News*, *19*, 1869, 302.)

IRON.

Regnault, Kopp and others have determined the specific heat of this metal. It corresponds to an atomic weight of about 56. (*Gmelin-Kraut*, *l. c.*)

L. J. THENARD: F. H. WOLLASTON: *55.2* (O = 16); 345 (O = 100).

Thenard determined the composition of the oxide at 22.5 O and 77.5 Fe, whence Wollaston calculates the value. (*Phil. Trans.*, *104*, 1814, 21.)

J. J. BERZELIUS: *54.27* (O = 16); 339.213 (O = 100).

Determined by repeated experiments on the oxidation of iron, such as is used for piano wire, with nitric acid. The carbon was determined and allowed for. Berzelius in his *Lehrbuch* shows that the error in this determination lay in the unsuspected presence of soluble silica and on reänalysis he found enough of it to correct the number when taken into account. (*Poggend. Ann.*, *8*, 1826, 185.)

G. MAGNUS: *54.25* (O = 16); *339.06* (O = 100).

Magnus' experiments were made by reducing ferric oxide in a current of hydrogen at about the temperature of boiling mercury. He regarded them simply as comfirmatory of Berzelius' number. (*Poggend. Ann.*, *3*, 1825, 84.)

F. STROMEYER: *55.6* (O = 16).

Determined by reducing ferric oxide at a red heat by hydrogen. The oxide is reduced only with great difficulty at a lower temperature. The mean of the experiments gave the oxygen contents at 30.15 per cent., [whence I have calculated the value.] (*Poggend. Ann.*, *6*, 1826, 475.)

that of silver at 107.928. [The sum of these weights is not the molecular weight, and this, as well as recalculation of the data, shows that the number is a misprint for 126.851. Stas' results are, therefore, even closer to Marignac's than his memoir would indicate.]

Most of the experiments were made with iodine prepared by the decomposition of nitric iodide decomposed in a large volume of water at 65°. The iodine was further purified by distillation over barium oxide and by other means. For the preparation of silver see that metal. All possible precautions were observed in the preparation of all reagents and in the conduct of the experiments. (*Stas, Untersuch. über Chem. Prop. Leipzig*, 1867.)

IRIDIUM.

Regnault determined the specific heat of iridium. It corresponds to an atomic weight of about 198. (*Gmelin-Kraut, l. c.*)

J. J. Berzelius: *197.19* (O = 16).

Berzelius determined this value from analysis of potassium chloro-iridiate. This salt reduced in hydrogen lost 29 per cent., the same quantity lost by the corresponding platinum salt, (*vide* platinum.) Berzelius originally calculated the atomic weight of the platinum metals both from the loss of chlorine of these double salts and from the relation between the metal and the potassic chloride left after reduction. In his *Lehrbuch* he points out the impossibility of complete desiccation, and resorts exclusively to the latter method of calculation. With respect to iridium he merely asserts that its atomic weight is the same as that of platinum, without there, or elsewhere, giving data as to the amounts of iridium and potassic chloride found in the reduced salt. It is, therefore, open to question whether he assumed the identity from the loss on reduction or not. [If Pt = Ir, and if KCl = 74.594, the value follows; see platinum.] Osmium and iridium were separated by fusion with nitre, solution, and distillation. The residue was fused with potassic chloride and sodium carbonate. On solution the iridium remains behind. This residue was repeatedly roasted and reduced to drive off osmium compounds. The potassium chloro-iridiate was formed from the pure metal. (*Poggend. Ann.*, *13*, 1828, 468; *Kongl. Vet. Acad. Handl.*, 1828.)

C. E. CLAUS: W. M. WATTS: 197.6 (O = 16).

Watts recalculated two analyses of potassium chloroiridiate by Claus from the loss in reduction, and for Cl = 35.457, (Stas.) From one analysis he finds K = 39.87, and Ir = 198.56; from the other K = 39.93, and Ir = 196.62. (*Chem. News*, *19*, 1869, 302.)

IRON.

Regnault, Kopp and others have determined the specific heat of this metal. It corresponds to an atomic weight of about 56. (*Gmelin-Kraut*, *l. c.*)

L. J. THENARD: F. H. WOLLASTON: *55.2* (O = 16); 345 (O = 100).

Thenard determined the composition of the oxide at 22.5 O and 77.5 Fe, whence Wollaston calculates the value. (*Phil. Trans.*, *104*, 1814, 21.)

J. J. BERZELIUS: *54.27* (O = 16); 339.213 (O = 100).

Determined by repeated experiments on the oxidation of iron, such as is used for piano wire, with nitric acid. The carbon was determined and allowed for. Berzelius in his *Lehrbuch* shows that the error in this determination lay in the unsuspected presence of soluble silica and on reänalysis he found enough of it to correct the number when taken into account. (*Poggend. Ann.*, *8*, 1826, 185.)

G. MAGNUS: *54.25* (O = 16); *339.06* (O = 100).

Magnus' experiments were made by reducing ferric oxide in a current of hydrogen at about the temperature of boiling mercury. He regarded them simply as comfirmatory of Berzelius' number. (*Poggend. Ann.*, *3*, 1825, 84.)

F. STROMEYER: *55.6* (O = 16).

Determined by reducing ferric oxide at a red heat by hydrogen. The oxide is reduced only with great difficulty at a lower temperature. The mean of the experiments gave the oxygen contents at 30.15 per cent., [whence I have calculated the value.] (*Poggend. Ann.*, *6*, 1826, 475.)

C. ERK: *135.39* (O = 16).

Determined by analysis of the sulphate by the method employed by Holzmann. The bases were separated by the methods which Hermann used. Yttrium was also eliminated. Fresenius in his *Zeitschrift*, *10*, 509, objects to the details of the Erk's manipulation of barium sulphate. (*Kopp's Jahresbericht*, 1870, 319; *Jena Zeitschr. für Med. und Nat.*, *6*, 1870, 299.)

D. MENDELEJEFF: 180 (O = 16).

As La forms but one oxide, the salts of which are not, according to Marignac, isomorphous with those of the lower oxide of didymium, Mendelejeff concludes that it belongs to the same group, but that its oxide is a binoxide, and its atomic weight 180. (*Liebig's Ann.*, *Suppl.*, *8*, 1871, 190.)

C. MARIGNAC: *138.75* (O = 16).

By heating the sulphate till all acid was expelled, Marignac, in two experiments, determined La (bivalent) at 92.52 and 92.56; by precipitation with ammonia and heating at 92.24 and 92.48. The sulphate was purified by a great number of partial recrystallizations, and showed only doubtful traces of didymium in the spectroscope. S = 16. (*Annal. de Chim. et de Phys.*, (4,) *30*, 1873, 67.)

P. T. CLEVE: 139.15 (O = 16).

Determined by the conversion of lanthanium oxide into sulphate. The number is the mean; extreme difference 0.55. The oxide was purified from didymium by repeated partial precipitation from nitric acid solution with ammonia, basic didymium nitrate going down. The lanthanium was finally precipitated with oxalic acid. The oxide was found to be spectroscopically pure by Thalén. (*Kopp's Jahresbericht*, 1874, 257; *Paris Bull. de la Soc. Chim.*, *21*, 196, 246, 344.)

LEAD.

Regnault, Kopp and others have determined the specific heat of lead. It answers to an atomic weight of about 207. (*Gmelin-Kraut*, *l. c.*)

J. J. BERZELIUS and F. H. WOLLASTON: *207.4* (O = 16); 1295 (O = 100).

Berzelius found 16.5 parts carbon di-oxide equal to 83.5 lead oxide, whence the value, if C = 75.4. [If C = 12, these figures give lead at 206.67.] Berzelius also determined the composition of the oxide at 7.15 oxygen and 92.85 lead, giving Pb = *207.52* or 1297. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *207.12* (O = 16); 1294.498 (O = 100).

Determined by the reduction of a known weight of oxide of lead by hydrogen and the weight of the resultant lead; mean of four nearly coincident experiments. (*Poggend. Ann.*, *8*, 1826, 184.

— Longchamp is credited in some books with an atomic weight determination of lead. He made none, but only speculated on the composition of minium, taking Berzelius' determination as a basis. (*Annal. de Chim. et de Phys.*, *34*, 1827, 105.)

J. J. BERZELIUS: *207.078* (O = 16); *1294.242* (O = 100).

This value is the mean of six experiments on the reduction of the oxide in a current of hydrogen. The oxide was produced by the decomposition of the nitrate by heat. As this compound reacts upon Pt, the crucible was lined out with a coating of a very basic nitrate, which prevented the lumps of neutral salt from coming in contact with the crucible. The glass in which the oxide was reduced was not attacked. [The third analysis is miscalculated. It should show an atomic weight of 1295.595. The mean is, therefore, as above, and the extreme difference 2.421.] (*Poggend. Ann.*, *19*, 1830, 314.)

J. J. BERZELIUS: *207.14* (O = 16); 1294.645 (O = 100).

In his *Lehrbuch*, Berzelius selects five analyses made by the above method, three of them the same. These give the above mean, with an extreme difference of 0.704 for O = 100. (*Lehrbuch*, *3*, 1219.)

E. TURNER: *207.3* (O = 16).

Determined by experiments on the conversion of metallic lead and of oxide of lead into the sulphate by solution in

nitric acid and evaporation with sulphuric acid. In three experiments, Turner found 100 lead = 146.401 sulphate; extreme difference 0.055. Berzelius had found 100 Pb = 146.419 sulphate; extreme difference 0.078. Turner takes the mean of his own and Berzelius' determinations, 146.41. In one experiment Turner found 100 oxide = 135.92 sulphate. Combination of these results gives Pb = 103.6 [or more accurately 103.65.] The oxide was prepared from subnitrate. The lead was prepared from plumbic acetate which was converted into carbonate, then into nitrate, in which form it was recrystallized, then again into carbonate, and reduced by black flux. On testing, it was found perfectly pure. Weighings reduced to vacuum. (*Phil. Trans.*, *123*, 1833, 524.)

C. MARIGNAC: 207.04 (O = 16).

Marignac made four experiments on plumbic chloride by Pelouze's modification of the silver titration method. He found Pb = 103.57–.49–.55–.46. The number taken is the mean. The salt was titrated cold, argentic chloride being soluble in hot solutions of plumbic nitrate. The plumbic chloride was purified by recrystallization, and, after being pulverized, was dried at about 200°. According to Marignac there is no difficulty in desiccating it completely at this temperature. Ag = 108; Cl = 35.5. Marignac found it impossible to convert the chloride into the sulphate completely. (*Bibl. Univ.*, *Arch. des Sciences*, (2,) *1*, 1858, 223.)

J. DUMAS: 207.1 (O = 16).

From a single experiment on the precipitation of the chloride with argentic nitrate. The chloride used was heated for twelve hours in a current of dry HCl, and the amount of water retained determined. Dumas found it impossible entirely to desiccate the salt without decomposition, drying at 250° does not desiccate it. Cl = 35.5; Ag = 108. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

J. S. STAS: 206.926 (O = 16).

According to the mean of 10 syntheses of plumbic nitrate, 100 lead = 159.9703 nitrate; extreme difference, 0.023. If N = 14.044, this relation gives Pb = 206.918. Stas also made six syntheses of the sulphate, which gave in mean 100 Pb = 146.4275 sulphate; extreme difference, 0.024. If S = 32.0742, this relation gives Pb = 206.934. The syntheses were made in the same way as in the determination of the

atomic weight of silver. The drying of the nitrate could be accomplished only *in vacuo* and at about 155°. The weighings are for vacuum. The lead used was prepared from commercial acetate by precipitation with metallic lead, of copper, etc., conversion into sulphate, then into carbonate and reduction by potassic cyanide or black flux. (*Stas, Untersuch. über Chem. Prop. Leipzig*, 1867, 324.)

LITHIUM.

Regnault has determined the specific heat of lithium. It corresponds to an atomic weight of about 7. (*Gmelin-Kraut, l. c.*)

The earliest determinations of this constant seem to have been made with a double salt of lithium and potassium, at all events with a very impure material. According to Arfvedson, 420.4 lithium chloride give 1322.4 argentic chloride, whence he deduces as the atomic weight the number 127.757 [or 10.22.] (*Poggend. Ann.*, *8*, 1826, 189.) L. N. Vauquelin found 430 lithium sulphate equivalent to 875 barium sulphate. [If S = 32; Ba = 137.08, this relation gives Li = 9.27.] Vauquelin does not describe the preparation of his salt. (*Annal. de Chem. et de Phys.*, *7*, 1818, 287.) C. G. Gmelin found Li = 191.21 [or 7.65.] (*Poggend. Ann.*, *15*, 480; *Gilbert's Ann.*, *62*, 1819, 399.) Kralovanszky by two analyses of the sulphate with barium chloride got Li at from 10.096 to 10.168 (*Liebig's Ann.*, *121*, 94; *Schweigger's Journ.*, *54*, 1828, 231.) Thomson and Stromeyer also each got similar values. (*Thomson's System of Chem.*, 7th ed., *1*, 1831, 420.)

R. Hermann: *6.085* (O = 16); 38.03 (O = 100).

Experiments were made on the carbonate by decomposing it with acid over mercury, and measuring the resultant di-oxide. For C = 75.33, these determinations give Li = 38. Several experiments were also made by analyzing the sulphate with barium chloride. For S = 201.06 and Ba = 856.88, these give Li = 38.05. Hermann precipitated lithium carbonate with ammonium carbonate, and subsequently converted it into sulphate. The chloride was prepared from the phosphate by Berzelius' method. (*Poggend. Ann.*, *15*, 1829, 480.)

J. J. BERZELIUS: *6.533* (O = 16); 40.83 (O = 100).

Berzelius found that 1.874 lithium sulphate gave 3.9985 barium sulphate, and calculated this relation for S = 200.75; Ba = 855.29. He also found 4.4545 melted carbonate = 6.653 sulphate, but rejected the analysis. (*Lehrbuch*, *3*, 1229, and *Jahresbericht*, *10*, 1830, 96.)

R. HAGEN: *6.57* (O = 16).

Hagen precipitated lithium sulphate with barium chloride, and found that 0.852 dry lithium sulphate gave 1.8195 barium sulphate whence he calculates Li = 6.493. [If Ba = 137.08; S = 32; this relation gives Li = 6.57.] (*Poggend. Ann.*, *48*, 1839, 363.)

J. W. MALLET: 6.95 (O = 16); 86.89 (O = 100).

In two experiments a known weight of lithium chloride was precipitated by argentic nitrate, and the argentic chloride weighed. In one experiment lithium chloride was titrated with argentic nitrate by Pelouze's method. The number is the mean; the extreme difference is 0.18 for O = 100. Mallet takes Ag = 1349.66; Cl = 443.28. The alkalis were separated from the lithium salt by repeated treatment with ether and alcohol. The salt was examined for impurities, and was fused with a little ammonium chloride to prevent the formation of oxy-chloride. (*Silliman's Amer. Journ.*, (2,) *22*, 1856, 349.)

L. TROOST: 6.5 (O = 16).

Troost found this number from analysis of the carbonate which had been crystallized from water containing carbon di-oxide and dried at 200°, but does not regard it as definitive. (*Annal. de Chim. et de Phys.*, (3,) *51*, 1857, 111.)

J. W. MALLET: 7 (O = 16).

Troost having objected to Mallet's former method of determination, he redetermined it by precipitating the sulphate with a standard solution of barium chloride, the precipitating power of which had been tested on the sulphates of magnesium and sodium. This method was adopted to avoid the well-known imperfections of the sulphur determination. Compared with sodium sulphate the atomic weight of Li was found = 6.92 and 6.95. Compared with magnesium sulphate it was found = 7.07 and 7.09.

Mg = 24; Na = 23. The sulphate was prepared from carbonate, and dried somewhat below a red heat. (*Silliman's Amer. Journ.*, (2,) *28*, 1859, 349.)

K. DIEHL: 7.026 (O = 16).

Determined by analysis of lithium carbonate with Bunsen's apparatus and in his laboratory. Four experiments; extreme difference, 0.024. C = 12. The salt was purified from alkalis by precipitation as carbonate, resolution in acid and reprecipitation, repeated until the sodium line was no longer visible. Diehl found that precipitation of the sulphate with barium chloride gave a nearly constant error on account of the retention of lithium in the precipitate, and led to nearly the same results as Berzelius got. (*Liebig's Ann.*, *121*, 1862, 93.)

L. TROOST: 7 (O = 16).

Troost found 1.309 grammes lithium chloride = 4.42 argentic chloride, and 2.75 lithium chloride = 9.3 argentic chloride. From these analyses he deduces the values 7.03 and 6.99. By decomposing the carbonate, dried at 100°, with silicic acid, he found 0.97 carbonate = 0.577 carbon di-oxide and 1.782 carbonate = 1.059 di-oxide, and infers for Li 7 and 7.02. In one experiment the carbonate was converted into sulphate. 1.217 carbonate gave 1.808 sulphate. Troost calculates Li = 7.06. [If Cl = 35.457; Ag = 107.93; C = 12; S = 32; these determinations give, in the same order as above, 7.01; 6.94; 6.98; 7.02; 7.07.] The carbonate was purified by solution in water containing carbon di-oxide, and reprecipitation by boiling, the operation being repeated until the salt was spectroscopically pure. (*Paris Comptes Rend.*, *54*, 1862, 366.)

J. S. STAS: 7.022 (O = 16).

According to the mean of three determinations, 100 parts of silver = 39.358 lithium chloride; extreme difference, 0.005. If Ag = 107.93; Cl = 35.457; this ratio gives Li = 7.022. This value is confirmed by experiments on the conversion of the chloride into the nitrate, the results of which give Li = 7.018. The comparison with silver was made according to Pelouze's modification of the silver titration method. The chloride was purified from alkalis, after preliminary treatment with ether and alcohol, by pouring the dissolved salt into a boiling solution of ammonium car-

bonate containing ammonia in excess. All weighings reduced to vacuum. (*Stas, Untersuch. über Chem. Prop., Leipzig*, 1867.)

MAGNESIUM.

Regnault and Kopp have each determined the specific heat of this metal. It answers to an atomic weight of about 24. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *25.3* (O = 16); 158.139 (O = 100).

Determined by dissolving magnesium oxide in dilute sulphuric acid, evaporating and heating to incipient redness. 100 oxide were found = 293.985 sulphate. The sulphate was perfectly soluble in water and had therefore lost none of its acid. The oxide was purified by solution in an aqueous solution of carbon di-oxide and reprecipitated by boiling. S = 200.75. (*Poggend. Ann., 8*, 1826, 188; and *Lehrbuch, 3*, 1227.)

Marchand and Scheerer recalculated this analysis for S = 200 and reached the value 157.74. They assert that the oxide may have contained alkalis and that the sulphuric acid carries off magnesium sulphate in volatilizing. (*Erdmann's Journ. für Prak. Chem., 50*, 1850, 392.)

W. HENRY: F. H. WOLLASTON: *23.36* (O = 16); 146 (O = 100).

Henry found that magnesium sulphate contained 33 per cent. magnesium oxide. If S = 200 the value follows. (*Phil. Trans., 104*, 1814, 21.)

— LONGCHAMP: *15.35* (O = 16).

In two experiments, Longchamp found that five parts of crystallized magnesium sulphate are equivalent to 4.91 barium sulphate. [If Ba = 137.08; S = 32, the number follows.] Longchamp found 53 per cent. water which is much too high. According to Marchand and Scheerer, the data for the anhydrous salt give Mg = 97.37, for S = 200; Ba = 856.8, [or 15.74.] (*Annal. de Chim. et de Phys., 12*, 1819, 265.)

L. J. GAY-LUSSAC: *23.62* (O = 16).

16.205 grammes crystallized sulphate were found equal to 15.345 barium sulphate, and 19.395 magnesium sulphate

to 18.3455 barium sulphate. Calculating from the anhydrous salt Gay-Lussac found from these experiments respectively Mg = 147.23 and Mg = 148.09 for Ba = 856.8; S = 200. The salt was found to contain 51.43 water. [Calculated from the anhydrous salt these data give Mg = 23.55 and 23.68. Calculated from the hydrous salt (7 molecules water) the numbers give 24.14 and 24.41, if S = 32; Ba = 137.08.] Gay-Lussac remarks that the sulphate is partially decomposed at a red heat. (*Annal. de Chim. et de Phys.*, *13*, 1820, 308.)

T. Scheerer: *24.16* (O = 16); 150.97 (O = 100).

Mean of six experiments on the precipitation of the sulphate with barium chloride. Extreme difference, 0.79. S = 200.75; Ba = 855.29. After weighing, the barium sulphate was treated with dilute HCl and the chloride thus extracted allowed for. (*Poggend. Ann.*, *69*, 1846, 535.)

T. Scheerer: *24.21* (O = 16); 151.33 (O = 100).

Barium sulphate formed as in the last determination was fused with soda, the barium carbonate dissolved in HCl, and reprecipitated as sulphate. In the filtrate additional magnesia was found. If the error in the former determination was the same, its corrected value would be as above. (*Poggend. Ann.*, *70*, 1847, 407.)

Svanberg and Nordenfeldt: *24.72* (O = 16); 154.504 (O = 100).

Four experiments were made on the calcination of the oxalate, and three on the conversion of the magnesia so obtained into sulphate. The oxalate was dried at from 100° to 105° and heated to redness until the weight was constant. The oxide was dissolved in sulphuric acid, evaporated and the excess driven off by heat. The oxalate was prepared from the sulphate by precipitation with sodium carbonate and digestion with oxalic acid. The number is the mean of all experiments; extreme difference, 0.514. S = 200.75; C = 75.12; H = 12.48. (*Erdmann's Journ. für Prak. Chem.*, *45*, 1848, 473.)

According to Marchand and Scheerer, the data give Mg = 154.27 for S = 200; H = 12.5; C = 75.

Marchand and Scheerer: *24.03* (O = 16); 150.19 (O = 100).

Eleven experiments were made in calcining massive magnesium carbonate from Frankenstein, and weighing the

caustic magnesia formed. The carbonate was dried at 300°, and the carbon di-oxide, which passes off above 230°, was caught by caustic baryta solution and determined. The traces of carbon di-oxide not expelled by a yellow heat were set free by solution in chlorhydric acid and also determined as barium carbonate. The silicic acid, etc., were also determined. The mean in air is 150.34; *in vacuo* as above. Extreme difference, 0.57. C = 75. Eleven other experiments were made with comparatively impure material and less precaution, tending to confirm the above. (*Erdmann's Journ. für Prak. Chem.*, *50*, 1850, 409.)

T. SCHEERER: 24 (O = 16); 150 (O = 100).

By separating the neutral sulphates of magnesium and calcium by means of alcohol, Scheerer found that the magnesites used by Marchand and himself contained from one-fourth to one-half per cent. calcium oxide. This correction would make their determination almost exactly 250 or 24. (*Liebig's Ann.*, *110*, 1858, 236.)

V. A. JACQUELIN: *24.408* (O = 16); 152.55 (O = 100).

Anhydrous, neutral magnesium sulphate, obtained by solution of the oxide in sulphuric acid and heating to redness, gave 33.56 per cent. pure oxide. The method adopted is not described. This oxide by treatment with sulphuric acid gave the original amount of sulphate. If S = 200, the number follows. (*Annal. de Chim. et de Phys.*, (3,) *32*, 1851, 195.)

A. MACDONNELL: 23.9 (O =16).

Determined from analyses of anhydrous and of crystallized magnesium sulphate. (*Brit. Assoc. Rep.*, 1852, part 2, 36; and *Kopp's Jahresbericht*, *5*, 364.)

J. F. BAHR: *24.77* (O = 16); 154.842 (O = 100).

A known weight of purified magnesium oxide was dissolved in sulphuric acid, evaporated and heated to redness till the weight was constant. The number is the mean of three experiments; extreme difference, 0.515. The oxide was obtained from meteoric olivin. After removal of the heavy metals, the solution was evaporated to dryness with soda, washed and heated to redness. The oxide so obtained was dissolved in acetic acid, oxalic acid was added, the

solution evaporated nearly to dryness, and the oxalate thoroughly washed. Bahr says that the presence of alkalis could not be suspected. S = 200. (*Erdmann's Journ. für Prak. Chem.*, *56*, 1852, 310; *Œfversigt af Akad. Færh.*, 1851, 303.)

Scheerer says that oxide so prepared retains carbonic acid, that sulphate is carried off in heating the sulphate to redness, and that the presence of alkalis is to be suspected. (*Erdmann's Journ. für Prak. Chem.*, *56*, 1852, 489.)

J. Dumas: 24.6 (O =16).

Dumas made eleven experiments on the titration of magnesium chloride with argentic nitrate. He found great difficulty in preparing pure chloride, and does not feel confident of his results. The number is the mean; extreme difference, 0.28. Ag = 108; Cl = 35.5. The chloride was prepared from various salts, but was in all cases finally heated in an atmosphere of HCl. Dumas points out, however, that this process does not remove oxide if present. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

MANGANESE.

Regnault has determined the specific heat of manganese. It corresponds to an atomic weight of about 55. (*Gmelin-kraut, l. c.*)

J. J. Berzelius: *56.93* (O = 16); 355.787 (O = 100).

By dissolving manganese in nitric acid, evaporating and heating to a low red, Berzelius found 100 Mn = 142.16 oxide. It was not known at the time that the oxide might be partially reduced by this process. (*Poggend. Ann.*, *8*, 1826, 185; and *Jahresbericht*, *9*, 136.)

J. A. Arfvedson: *56.25* (O = 16); 351.56 (O = 100).

From 1.508 chloride Arfvedson obtained 3.408 argentic chloride. If Ag = 1351.607; Cl = 221.325; the number follows. (*Berzelius' Jahresbericht*, *9*, 1829, 136; *Afhandl. i. Fysik.*, 6, 236.)

E. TURNER: *54.9* (O = 16).

Turner analyzed the carbonate in an apparatus similar to Bunsen's. He found 34.72 per cent. carbon di-oxide and 8.427 water. For C = 6, he calculates Mn = 28.024. By dissolving the protoxide in sulphuric acid, evaporating and heating to redness, he found 9 oxide = 19.01 sulphate. If S = 16, this gives Mn = 27.96. A second experiment gave 27.93. From 12.47 Mn chloride he obtained 28.42 argentic chloride. [If Cl = 35.5, Ag = 108; this gives Mn = 54.9.] The carbonate was obtained by precipitation with potassium carbonate. The protoxide was obtained by reduction of higher oxides in hydrogen. The chloride was melted in a current of HCl gas. (*Edinb. Trans.*, *11*, 1831, 143.)

J. J. BERZELIUS: *55.34* (O = 16); 345.9 (O = 100).

Berzelius repeated Turner's experiments, taking larger quantities. From the chloride he got from 345.84 to .96; from the sulphate from 346.03 to .29. Ag = 1351.607; Cl = 221.325; S = 201.165. (*Berzelius' Jahresbericht*, *9*, 1830, 136.)

J. J. BERZELIUS: *55.14* (O = 16); 344.684 (O = 100).

In his *Lehrbuch* he apparently takes the analyses of the chloride above cited, recalculated for Cl = 221.64; Ag = 1349.66. (*Lehrbuch*, *3*, 1224.)

R. BRANDES: *57.06* (O = 16); 356.602 (O = 100).

Determined by analysis of crystallized chloride. The chlorine was determined by precipitation with silver. The Mn was precipitated as carbonate, and converted into oxide by heat. The water was determined by difference, and the composition of the oxide was assumed to be as given by Berzelius, (!) whose values for Ag and Cl were also taken. (*Poggend. Ann.*, *22*, 1831, 256.)

K. VON HAUER: 54.98 (O = 16); 343.632 (O = 100).

Determined by nine experiments on the reduction of the sulphate to sulphide by heating the salt in a current of hydrogen sulphide. The reduction was performed in a porcelain tube enclosed in a charcoal fire. Number, mean; extreme difference, 0.34, for O = 16. The sulphate was prepared from a pyrolusite containing only silica, iron, and barium. It was reduced to protoxide, dissolved in sulphuric acid, oxidized with nitric acid, precipitated with oxalic

acid, converted into red oxide, dissolved in chlorhydric acid and alcohol, precipitated with ammonium carbonate, dissolved in sulphuric acid, repeatedly heated to redness and recrystallized, and was dried at 300°. Accurate experiments on the reduction of the red oxide proved impracticable on account of the hydroscopicity of the compound. Two experiments on the oxidation of the protoxide, undertaken as a check on the other method, gave 27.486 and 27.527 for O = 8; S = 16. (*Erdmann's Journ. für Prak. Chem.*, *72*, 1857, 361; *Sitz.-Bericht der k. k. Akad.*, 1857.)

J. Dumas: 54.96 (O = 16).

Determined by the decomposition of the chloride with argentic nitrate. The number is the mean of five experiments; extreme difference, 0.1 for O = 16. Cl = 35.5; Ag = 108. Dumas had previously made experiments on the reduction of the hyperoxide to protoxide by hydrogen. These gave the atomic weight at from 25.99 to 26.09 for O = 8. Dumas believes that a part of the oxide was reduced to metal. The peroxide was prepared from nitrate of the protoxide. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 150.)

— Rawack: 54.02 (O = 16).

Determined, in Schneider's laboratory, by reducing a known weight of red oxide to protoxide in a current of dry hydrogen, and weighing the water formed. The number is derived from the mean of six selected experiments. The extreme difference is 0.22 for O = 16. (*Poggend. Ann.*, *107*, 1859, 607.)

R. Schneider: 54.038 (O = 16).

The mean result of four analyses of the oxalate by the ordinary method of organic analysis. Extreme difference, 0.04 for O = 16. C = 12. The oxalate was prepared from chemically pure sulphate by precipitation with sodium carbonate, digestion with oxalic acid, and drying over sulphuric acid. (*Poggend. Ann.*, *107*, 1859, 613.)

MERCURY.

The specific heat of mercury in the solid state, as observed by Regnault, and the vapor density, as determined by Dumas, correspond to an atomic weight of slightly above 200. (*Gmelin-Kraut, l. c.; L. Meyer, l. c.*)

FOURCROY AND THENARD, DAVY, WOLLASTON: *200.8* (O = 16); 1255 (O = 100).

Fourcroy and Thenard found 8 O = 100 Hg. Davy found 30 O = 380 Hg, giving Hg = 1266. The latter also found 134 Cl = 380 Hg, which for Cl = 441, gives Hg = 1254. (*Phil. Trans.*, *104*, 1814, 21.)

N. G. SEFSTROEM: 202.53 (O = 16); 1265.822 (O = 100).

Determined by three analyses of the oxide according to which 100 Hg = 7.89, 7.9, and 7.97 O. (*Berzelius' Lehrbuch*, *3*, 1215.)

E. TURNER: *200.72* (O = 16).

Turner made a number of determinations of this atomic weight but regarded the value he adopted, 202, only as an approximation. From the oxide, prepared from nitrate, he got 200.77 and 199.97. The compound was decomposed by heat, and the products carried over silver and gold in a narrow tube. Four experiments were made on mercuric chloride which was decomposed by pure calcic oxide, and the Cl precipitated with argentic nitrate. [These analyses recalculated for the Stas' atomic weights of Ag and Cl give 202.079, 201.701, 201.815.] Turner also made two experiments on the reduction of the chloride with stannous chloride, the Hg being collected, dried and weighed. [These experiments recalculated give 199.423 and 199.289.] The mercuric chloride was purified by recrystallization. Weighings reduced to vacuum. (*Phil. Trans.*, *123*, 1833, 535.)

ERDMANN AND MARCHAND: *200.14* (O = 16); 1250.6 (O = 100).

Determined from the mean of four experiments on the reduction of the oxide in a current of carbon di-oxide. Copper, carbon (from sugar) oxide, and carbon, were introduced in successive layers in a combustion tube. Dry carbon di-oxide was passed through and the mercuric oxide heated. The metal was collected in a receiver to which a tube filled with gold foil was appended. The metal was perfectly clean. Moisture was removed by a stream of dry air after distillation. The oxide was purified by heating it to incipient decomposition the metallic fumes being removed

by a current of dry air. It was tested before being analysed. The extreme difference in the results was 0.8 for O = 100. All weighings *in vacuo*. (*Erdmann's Journ. für Prak. Chem.*, *31*, 1844, 392.)

E. MILLON: *199.94* (O = 16); 1249.63 (O = 100).

Millon made two experiments by heating mercuric chloride with calcic oxide in a current of hydrogen and condensing the metal. The experiments gave 73.87 and 73.82 per cent. mercury. If Cl = 442.64, the value follows. The chloride was dissolved in ether and sublimed. It was perfectly soluble in ether and alcohol, and was well crystallized. (*Paris Comptes Rend.*, *20*, 1845, 1291.)

L. SVANBERG: *200* (O = 16); 1250 (O = 100).

Svanberg made three experiments by the same method employed by Millon. The mean result was 1248.47; extreme difference, 0.94; but Svanberg shows that there was probably loss, and that the larger the quantity of chloride employed the higher the result. He regards Erdmann and Marchand's result as most probable, but in need of confirmation. Cl = 443.28. (*Erdmann's Journ. für Prak. Chem.*, *45*, 1843, 468; *Kongl. Vet. Akad. Handl.*, 1845, 135.)

MOLYBDENUM.

Regnault determined the specific heat of molybdenum. It answers to an atomic weight of about 96. (*Gmelin-Kraut*, *l. c.*)

J. J. BERZELIUS: *95.36* (O = 16); 596.1 (O = 100).

One hundred parts of anhydrous plumbic nitrate, dissolved and precipitated with neutral ammonium molybdate, gave 110.68 parts plumbic molybdate. If Pb = 1294.645, N = 87.53, the value follows. Berzelius expresses himself dissatisfied with the accuracy of the determination. (*Poggend. Ann.*, *8*, 1826, 23; and *Lehrbuch*, *3*, 1208.)

SVANBERG AND STRUVE: *92.13* (O = 16); 575.829 (O = 100).

After trying various methods without getting accordant results, these chemists made ten experiments on the sul-

phide by roasting it first in a current of moist, and then of dry air. Three experiments were excluded as imperfect. The remainder gave a mean of 89.7523 molybdic acid from 100 sulphide; extreme difference, 0.22. The value follows for S = 200. Objections have been made (*Liebig's Ann.*, *68*, 211) that the difference in weight between the acid and the sulphate is too small for the purpose of the determination, and that the different analyses give very different atomic weights. The sulphide was prepared by melting together molybdic acid, sulphur, and caustic potash, and leaching the product with water and chlorhydric acid. The sulphide was dried in a current of hydrogen. The molybdic acid was dissolved in ammonia to prove the absence of sulphide. (*Erdmann's Journ. für Prak. Chem.*, *44*, 1848, 315.)

N. J. BERLIN: *91.96* (O = 16); 574.75 (O = 100).

Determined by four analyses of the double mono-sesquimolybdate of ammonium by heating gently with nitric acid in a platinum crucible until only molybdic acid was left. Extreme difference, 3.32 for O = 100; N = 175; H = 12.5. The preparation of the salt is not given. (*Erdmann's Journ. für Prak. Chem.*, *49*, 1850, 446.)

J. DUMAS: 96 (O = 16).

Dumas made five experiments on the reduction of molybdic acid (prepared from the natural sulphide) by means of hydrogen. The reduction was begun at a low temperature in a glass tube, and completed in an unglazed porcelain tube in a reverberatory furnace, where it was kept till several hours heating produced no further alteration in weight. The molybdenum did not assume a metallic appearance. The number is the mean; extreme difference, 0.8 for O = 16. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 142.)

M. DELAFONTAINE: *92* (O = 16); 575 (O = 100).

This chemist made many experiments in various ways without being able to reach constant results, and only remarks that his experiments indicate Svanberg and Struve's value as the best. (*Erdmann's Journ. für Prak. Chem.*, *95*, 1865, 137; *Bibl. Univ.*, *Arch. des Sciences*, *23*, 1865.)

H. DEBRAY: 95.94 (O = 16).

Debray made three experiments on the reduction of molybdic acid. The acid was first converted into the red

oxide in platinum, and at a low temperature, and the small portion of the acid volatilized during this operation was caught and determined. The reduction was completed in a porcelain tube at a white heat. Debray gives his results at 48.03; 48.04; and 47.84. [The analytical data, recalculated, give 95.30; 95.55; 95.73; perhaps on account of misprints. Reduction to vacuum would still further reduce the numbers.] The acid was purified by sublimation in platinum, conversion into ammonium salt, and regeneration by heat. In two experiments ammoniacal solution of molybdic acid was evaporated in the dark with excess of argentic nitrate, the argentic molybdate dissolved out and the excess of silver determined. Debray found 5.510 acid = 7.657 silver, and 7.236 acid = 10.847 silver. Hence he calculates M = 48 and 47.98. [A little calculation shows that the first data are misprinted. They should read 5.11 acid = 7.657 silver. The corrected data give for Ag = 107.93; M = 96.06 and 95.99. The mean of the recalculated analyses is 95.73.] (*Paris Comptes Rend.*, *66*, 1868, 732.)

L. Meyer: *96.10* (O = 16).

Calculated from three analyses of the dichloride, two analyses of the tetrachloride, and two analyses of the pentachloride, made by Leichte and Kempe in Meyer's laboratory. The dichloride was analyzed by heating in a current of hydrogen sulphide, and subsequently in a current of hydrogen. Molybdenum disulphide is the residue. The HCl formed was caught in ammonium hydrate and precipitated by argentic nitrate, after the hydrogen sulphide had been driven off by boiling in a flask provided with a condensing drip-tube. The tetra and pentachloride were decomposed with nitric acid, excess of ammonium hydrate was added, and molybdenum trisulphide precipitated with ammonium sulphide. A weighed portion of the dry precipitate was converted into disulphide by heating in a current of hydrogen. The chlorine of the higher chlorides was determined in the filtrate after precipitation of the trisulphide. By comparing the amount of chloride analyzed with the amount of argentic chloride obtained, Meyer finds in mean M = 95.92; extreme difference, 1.87 for O = 15.96. By comparing the amount of disulphide with that of argentic chloride, M = 95.75; extreme difference, 1.35. By comparing the amount of chloride analyzed with the amount of disulphide obtained for one analysis of tetrachloride and two analyses of pentachloride, he gets M = 95.94; extreme difference, 2.15. The general mean is M = 95.86; extreme

difference, 2.15. Ag = 107.66; S = 31.98; Cl = 35.37; O = 15.96. The specific gravities of the chlorides not having been determined, the weighings are not reduced to vacuum. The pentachloride was prepared from M by heating it in a current of Cl entirely free from air. The metal had been freed from oxide by heating in an atmosphere of HCl. By moderate heating of the pentachloride in dry H, and by distilling pentachloride over the product in dry carbon di-oxide, the trichloride is obtained. The trichloride heated in carbon di-oxide is decomposed into tetrachloride and di-chloride, which latter must be purified with warm dilute nitric acid. (*Liebig's Ann.*, *169*, 1874, 360, 344.)

NICKEL.

Regnault has determined the specific heat of nickel. It corresponds to an atomic weight of about 59. (*Gmelin-Kraut, l. c.*)

E. Rothoff: *59.09* (O = 16); 369.333 (O = 100).

Rothoff converted 188 parts of oxide into chloride, a neutral solution of which gave 718.2 parts argentic chloride. If Cl = 221.64, Ag = 1349.66, the value follows. (*Berzelius' Lehrbuch*, *3*, 1221.)

P. Berthier.

Lassaigne having announced the atomic weight of nickel at 500, (*Schweigger's Jahrbuch*, *9*, 108,) Berthier re-examined the subject and found Rothoff's number confirmed. (*Berzelius' Jahresbericht*, *5*, 1825, 148; *Annal. de Chim. et de Phys.*, *26*, 1824, 148.)

Erdmann and Marchand: *58.2* (O = 16); 365.9 (O = 100).

Determined "with all precaution" by the reduction of the oxide with hydrogen. The results varied from 29.1 to 29.3, but Erdmann has reason to believe the smaller number the more accurate. (*Erdmann's Journ. für Prak. Chem.*, *55*, 1852, 202.)

H. SAINTE-CLAIRE DEVILLE:

100 parts fused nickel, containing three-tenths per cent. silicon and one-tenth per cent. copper, gave 262 parts anhydrous, yellow nickel sulphate, "corresponding to the atomic weight as given by Berzelius." (*Annal. de Chim. et de Phys.*, (3,) *46*, 1856, 182.)

R. SCHNEIDER: 58.05 (O = 16); 362.8 (O =100).

Determined from four analyses of the oxalate. The carbon determinations were made by the ordinary method of organic analysis, because some hydrocarbon forms when the salt is decomposed by heat alone. The metal was determined by heating a known weight of the salt first in air and then in a current of oxygen, and subsequent reduction by hydrogen. In the preparation of the salt the usual precipitate with ammonium sulphide was washed with dilute chlorhydric acid, and the cobalt separated with barium carbonate and chlorine. From the nickel salt obtained the oxalate was precipitated with oxalic acid. The number is the mean of four analyses; extreme difference, 0.082 for O = 8. (*Poggend. Ann. 101*, 1857, 396.)

C. MARIGNAC: 59 (O = 16).

Marignac made two analyses of the sulphate by decomposing the salt by heat. The decomposition is perfect. To avoid errors arising from possible reduction of a portion of the oxide, it was moistened with nitric acid, and recalcined at a moderate temperature. The results obtained were Ni = 29.2 and 29.5. The sulphate was purified by recrystallization. He also made experiments on the chloride by titration with argentic nitrate, according to Pelouze's modification of Gay-Lussac's method. Three such analyses gave from 29.4 to 29.5. In one experiment he also evaporated the nickel nitrate, after filtering off the argentic chloride, and converted it into oxide by heat. This experiment gave Ni = 29.64. The chloride, whether it be distilled or calcined with ammonium chloride, is apt to leave an insoluble residue the weight of which must be deducted. S = 16; Ag = 108; Cl = 35.5. (*Bibl. Univ. Arch. des Sciences*, (2,) *1*, 1858, 375.)

J. DUMAS: 59.028 (O = 16).

The number is the mean result of five experiments on the titration of the chloride with argentic nitrate; ex-

treme difference 0.08. Ag = 108; Cl = 35.5. In three cases the nickel chloride was prepared by dissolving fused nickel in aquia regia, repeated evaporation to dryness with HCl, and heating for from twelve to twenty-four hours in a current of HCl gas. In two cases it was produced by passing a current of chlorine over spongy nickel. The chloride analyzed was crystalline and volatile without residue. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 149.)

R. SCHNEIDER: 58.058 (O = 16).

In consequence of Marignac's criticism (that as nickel oxalate is insoluble it cannot be purified by recrystallization) Schneider repeated his former determination, making special tests for oxalic acid, sodium, and chlorine, with the above result. (*Poggend. Ann.*, *107*, 1859, 616.)

W. J. RUSSELL: 58.738 (O = 16).

Determined from the mean of thirteen experiments on the reduction of the oxide in hydrogen. Extreme difference, 0.12 for O = 16. The oxide was prepared from three specimens of commercial nickel, which were first converted into pure oxalate and then into nitrate. The oxide was obtained by decomposing the nitrate by a very strong heat. (*Journ. Chem. Soc.*, (2,) *1*, 1863, 61.)

Schneider remarks that a portion of the oxide analyzed may have been reduced during the process of decomposing the nitrate. (*Poggend. Ann.*, *130*, 1867, 310.) Marignac points out the same danger. (*Bibl. Univ.*, *Arch. des Sciences*, (2,) *1*, 374.)

E. VON SOMMARUGA: 58.026 (O =16).

Determined from the amount of barium sulphate obtained by precipitating the double sulphate of nickel and potassium with barium chloride. The number is the mean of six experiments; extreme difference, 0.168 for O = 8, S = 16; Ba [no doubt] = 68.5; K = 39.2. The salt was prepared by solution of commercial nickel in sulphuric and nitric acid, adding potassic sulphate to the solution, and repeatedly recrystallizing the double sulphate. (*Erdmann's Journ. für Prak. Chem.*, *100*, 1867, 115; *Sitz.-Ber. der k. k. Akad.*, 1866.)

C. WINKLER: 59.05 (O = 16).

Determined by the amount of gold precipitated from a solution of neutral crystallized potassium chloro-aurate by

a known weight of nickel. The number is the mean of four experiments; extreme difference, 0.186 for O = 16, Au = 196. The nickel was prepared as follows: commercial nickel carbonate was dissolved in chlorhydric acid, cobalt was repeatedly precipitated with sodium hypochlorite, copper, etc., were removed with hydrogen sulphide, the nickel was precipitated with sodium carbonate, the precipitate dissolved in chlorhydric acid, the chloride sublimed and reduced in a current of hydrogen. (*Fresenius' Zeitsch.*, *6*, 1867, 22.)

W. J. Russell: 58.76 (O = 16).

Determined by the amount of hydrogen set free by solution of nickel in chlorhydric acid. The nickel was that obtained in Russell's former determination of the atomic weight of nickel. (*Chem. News*, *20*, 1869, 20.)

R. H. Lee: 58.01 (O = 16).

Determined by analyses of nickel cyanide salts. They were decomposed in a platinum crucible by heat from above. The carbon separated out was burned off first in air and then in oxygen. The metallic oxide was reduced in a current of hydrogen. The mean of six experiments on the strychnine salt gave Ni = 58.04. The mean of six experiments on the brucine salt gave Ni = 57.98. The salts were purified by recrystallization. (*Berlin. Bericht der Chem. Ges.*, *4*, 1871, 790.)

NIOBIUM.

The vapor density of the chloride and of the oxychloride, as determined by Deville and Troost, places the atomic weight at about 94. (*Paris Comptes Rend.*, *56*, 1863, 891.)

H. Rose: *122* (O = 16).

Rose deduced the atomic weight of niobium from analyses of what he supposed to be the tetrachloride, determining the niobium as niobic acid, and the chlorine as argentic chloride. The results, which varied greatly, indicated the value 97.64. [Marignac having proved that the salt is a pentachloride, this number becomes 122.] Marignac showed

that Rose dealt with a compound containing a large amount of the corresponding tantalium chloride. (*Poggend. Ann.*, *104*, 1858, 439.)

ROSE; RAMMELSBERG: 94 (O = 16).

Rose analysed the oxychloride, but did not recognize it as an oxychloride. Rammelsberg calculated the atomic weight from Rose's figures and found that the highest chlorine contents corresponds to an atomic weight of 94. Rose's salt must have been nearly pure as there is no corresponding tantalium compound. (*Poggend. Ann.*, *136*, 1869, 353.)

R. HERMANN: 104.8 (O = 16).

Hermann deduces this value from analyses of a number of chlorides and sodium salts. The formulas which he gives these compounds are complicated, unlikely, and unsupported by evidence. Marignac has shown that Hermann's salts contained tantalium. (*Erdmann's Journ. für Prak. Chem.*, *68*, 1856, 73.)

C. W. BLOMSTRAND: 95 (O = 16).

Blomstrand made three determinations of the chlorine contents of the pentachloride, getting 64.712 per cent., extreme difference, 0.32. He also made eleven determinations of the niobium in the same compound, weighing it as niobic acid. 100 chloride gave in mean 49.794 acid. The atomic weight calculated from the chlorine contents is 96.67; from the niobic acid, 96.16. Blomstrand also made experiments on sodium niobate which led him to the conclusion that the most probable number is 95. (*Gmelin-Kraut*, *2*, part 2, 73; *Acta Univ. Lund.*, 1864.)

C. MARIGNAC: 94 (O = 16).

Determined from a number of analyses of potassium fluoniobate containing two atoms of potassium. The compound was decomposed by sulphuric acid with which it was evaporated to dryness. The residue was leached with water, the filtrate evaporated and the potassic sulphate melted and weighed. The sulphuric acid remaining with the niobic acid was driven off by heat and the acid weighed. The salt being readily soluble and crystallizing well, can easily be purified from all substances except titanium which Marignac knows no way of separating or determining.

The larger the amount of titanium present, the lower will the atomic weight be; Marignac therefore takes the highest value. (*Liebig's Ann.*, *S.* 4, 334, 288, 338; *Bibl. Univ.*, *Arch. des Sciences*, *23*, 1865, *25*, 1866.)

NITROGEN.

Regnault has determined the specific gravity of nitrogen. It indicates an atomic weight slightly above 14. (*Gmelin-Kraut*, *l. c.*)

BIOT and ARAGO; WOLLASTON: *14.03* (O = 16); 87.7 (O = 100).

Biot and Arago found the specific gravities of N and H 0.96913 and 0.07321. If H = 13.27 the value follows. [This very accurate value is of course the result of two compensating errors.] (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS; *14.163* (O = 16); 88.518 (O =100).

Calculated from the specific gravity as determined by Berzelius and Dulong, compared with that of oxygen. By decomposing the nitrate of lead by heat, Berzelius also found N = 88.61 for Pb = 1294.498. (*Poggend. Ann.*, *8*, 1826, 14.)

E. TURNER: 14.15 (O = 16).

Determined by experiments on the nitrates of lead, silver, and barium, which were precipitated with sulphuric and hydrochloric acids, and gave respectively N = 14.201; 14.09; 14.17; if Pb = 103.6; Ba = 68.7; Cl = 35.42; S = 16.085; the weighings being reduced to vacuum. The salts were purified by recrystallization. Turner recommends more direct methods. (*Phil. Trans.*, *123*, 1833, 537.)

T. THOMSON: *14* (O = 16).

From the hypothesis that air is a compound containing four parts of N and one part oxygen, and from the average of various selected determinations of the specific gravity of oxygen, Thomson concludes the specific gravity of oxygen is 1.1111, and that of N 0.9722. These numbers stand

[illegible]

[illegible]

[illegible]

ence, 0.063; Hence N = 87.655. The weighings are reduced to vacuum. (*Berzelius' Jahresbericht*, *24*, 1842, 44; *Bibl. Univ. de Genève*, *46*, 1842, 363.)

T. ANDERSON: *13.95* (O = 16); 87.204 (O = 100).

Determined by four experiments on the decomposition of plumbic nitrate by heat at a sufficiently low temperature to permit of complete decomposition. The number is the mean; extreme difference, 0.198 for O = 100. Pb = 1294.5. (*Annal. de Chim. et de Phys.*, (3,) *9*, 1843, 254.)

J. PELOUZE: *14.014* (O = 16); 87.59 (O = 100).

A known weight of argentic nitrate was brought in contact with a known and slightly excessive weight of ammonium chloride and the excess titrated with silver solution. One experiment gave N = 175.58; a second gave N = 174.78. Ag = 1349.01; Cl = 443.2. The ammonium chloride was purified by sublimation and recrystallization. (*Paris Comptes Rend.*, *20*, 1845, 1047.)

P. EINBRODT: *14* (O = 16); 87.5 (O = 100).

Experiments on the decomposition of plumbic nitrate by heat gave N = 87.5 plus a vanishing quantity if Pb = 1294.2239. (*Leibig's Ann.*, *70*, 1849, 286.)

J. DUMAS: 14 (O = 16).

Determined by experiments on the combustion of ammonia and cyanogen. Particulars not given. C = 6; H = 1. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 134.)

J. S. STAS: 14.044 (O = 16).

Stas made seven determinations of the relation between silver and its nitrate by dissolving pure silver in nitric acid, evaporating to dryness and keeping the salt melted until there was no further loss of weight. In two of these experiments the salt was melted *in vacuo*. The mean result was that 100 Ag = 157.472 nitrate; whence N = *14.040*. Later Stas made two more experiments by the same method with all possible precautions to secure accuracy. These gave 100 Ag = 157.484 nitrate and N = 14.042. By the conversion of the chlorides of potassium, sodium, lithium and silver into nitrates, Stas found the difference between a chloride and a nitrate 26.5882. This gives N = 14.045. The weigh-

ings are reduced to vacuum. Cl = 35.457; Ag = 107.93. (*Stas, Unters. über Chem. Prop. Leipzig*, 1867.)

OSMIUM.

Regnault has determined the specific heat of osmium. It corresponds to an atomic weight of about 199. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *199.04* (O = 16).

Berzelius analyzed potassium chloro-osmate by reduction in a current of hydrogen and solution of the potassium chloride from the residue. 1.3165 grammes of the double salt lost 0.3805 in reduction and the residue was composed of 0.401 potassium chloride and 0.535 osmium. The atomic weight may be calculated either from the chlorine lost or from the relation of the chloride to the metal in the residue. Berzelius preferred the latter as more probably accurate. [If K = 39.137; Cl = 35.457 (Stas;) this relation gives 199.04.] According to W. M. Watts, (Chem. News, *19*, 302) the loss of chlorine gives for Stas's values Os = 199.42. Hyperosmic acid was separated from iridium compounds by distilling at a gentle heat. The first portion is perfectly pure. The metal was precipitated from chlorhydric acid solution of hyperosmic acid by mercury and subsequently purified by heating in a current of hydrogen. Potassium chloro-osmate was formed by heating comminuted metal and KCl in a current of chlorine. (*Poggend. Ann.*, *13*, 1828, 530; *Kongl. Vet. Acad. Handl.*, 1828.)

E. FREMY: *199.65* (O = 16); 1247.8 (O = 100).

Pure osmium was burned in a current of oxygen and the fumes led over potassic hydrate, by which they are absorbed. An additional potash tube did not increase in weight. Corks were avoided. Number of experiments not given. (*Erdmann's Journ. für Prak. Chem.*, *33*, 1844, 409; *Journ. de Pharm. et Chim.*, 1844, 241.)

DEVILLE and DEBRAY: 198 (O = 16).

These chemists determined the vapor density of hyperosmic acid by Dumas' method, finding it 8.89 at 246°,

and 8.87 at 286°. They hence consider it probable that the atomic weight of osmium is the same as that of platinum. The acid was very pure and was prepared by the combustion of metallic osmium in oxygen. (*Paris, Comptes Rend.*, *44*, 1857, 1101.)

OXYGEN.

The atomic weight of oxygen is assumed at 16 for the reasons stated under hydrogen, q. v. If hydrogen is taken as unity, O = 15.96.

PALLADIUM.

Regnault determined the specific heat of palladium. It corresponds to an atomic weight of about 106. (*Gmelin-Kraut, l. c.*)

J. J. Berzelius; *106.51* (O = 16).

In his earliest determinations of this constant, Berzelius saturated the metal with sulphur, getting about 711 for S = 201.165; and decomposed the chloride with mercury, getting 704. [711 appears to be a misprint for 714.618 the number given with corresponding data at Poggend., *8*, 180.] In this investigation a known weight of potassium chloropalladate was reduced in a current of hydrogen, the weight of the residue determined, the potassium chloride leached from the residue and the metallic palladium weighed. The double salt was strongly heated, but not to fusion, in a current of dry air before weighing. It being impossible to desiccate this and the similar platinum-metal salts completely without decomposition, the atomic weight was calculated from the relation between the metal and the KCl. Berzelius found 0.575 Pd = 0.809 KCl, and 0.851 Pd = 1.192 KCl. [If KCl = 74.594 (Stas) the former gives Pd = 106.036, the latter 106.509.] Berzelius had reason to consider the latter analysis the more accurate. (*Poggend. Ann.*, *13*, 1828, 454; *Kongl. Vet. Acad. Handl.*, 1828.)

PHOSPHORUS.

The specific heat of this element, as well as the density of phosphorus and its numerous volatile compounds in the gaseous state, corresponds to an atomic weight slightly above 31. (*Gmelin-Kraut, l. c.*)

V. Rose; F. H. Wollaston: *35.1* (O = 16).

Wollaston adopted the analysis of Rose, who found that phosphoric anhydride contained 53.28 per cent. oxygen and 46.72 per cent. phosphorus. [This relation gives the above value.] (*Phil. Trans.*, *104*, 1814, 20.)

J. J. Berzelius: *31.325* (O = 16).

Berzelius made experiments on the reduction of auric chloride and of argentic sulphate by phosphorus. His results were 0.8115 P = 13.98 Ag; 0.829 P = 8.714 Au; 0.754 P = 7.93 Au. [The first of these analyses is misprinted in the original memoir (Gilbert's Ann., *53*, 433).] In the *Lehrbuch* it is miscalculated as Ruecker has shown. Berzelius preferred deducing the atomic weight of P from that of silver, because the atomic weight of the latter was more accurately known than that of gold. [If Ag = 107.93, the data give P = 31.325, for Au = 196.67 the latter analyses give P = 31.176 and 31.165.] In all the experiments the precipitated metal was boiled with the solution when the reduction was nearly complete. A trace of gold was observed to precipitate after the experiments were over. The silver was heated to redness before weighing. [J. P. Cooke, Jr., has shown (atomic weight of antimony) that silver is volatile at a red heat. Berzelius must therefore have got too large a result.] The phosphorus was distilled, melted in a glass tube and cooled very slowly, to permit traces of oxides to rise to the surface, and the lower portion of the tube with the phosphorus broken off and instantly weighed. (*Gilbert's Ann.*, *53*, 1816, 433, and *Lehrbuch 3*, 1188.)

J. Pelouze: *32.024* (O = 16); 200.15 (O = 100).

A known weight of argentic nitrate was brought in contact with a known and slightly excessive weight of phosphorous chloride and the excess titrated. The number of experiments is not given. Ag = 1349.01; Cl = 443.2.

The terchloride was prepared by chloridizing finely divided P with dry chlorine, adding finely divided P, decanting, agitation with tin amalgam and rectification over the same. The fluid was colorless and did not give any precipitate with water. (*Paris, Comptes Rend.*, *20*, 1845, 1047.)

V. A. JACQUELIN: *29.83* (O = 16); 186.438 (O = 100).

Determined by experiments on the chlorides of phosphorus with argentic nitrate and plumbic oxide. The results are utterly discordant. (*Paris, Comptes Rend.*, *33*, 1851, 693.)

A. SCHROETTER: 31.0274 (O = 16).

Determined by burning perfectly pure amorphous phosphorus in dry oxygen and weighing the phosphoric anhydride. The number is the mean of 10 experiments; extreme difference, 0.1242. Previous to burning, the phosphorus was heated for a long time in carbon di-oxide or hydrogen. It was burned not in powder but in lumps. (*Erdmann's Journ. für Prak. Chem.*, *53*, 1851, 435; *Sitz.-Bericht der k. k. Akad.*, 1851.)

B. C. BRODIE: 31.31 (O = 16).

Three experiments made by oxidation of phosphorus with aqua regia and determination as magnesium pyrophosphate gave this mean. Brodie seems to regard these determinations only as evidence that the atomic weight needs redetermination. (*Journ. Chem. Soc.*, *5*, 1852, 295.)

J. DUMAS: 31.03 (O = 16).

Determined by five experiments on the titration of the terchloride with argentic nitrate. The chloride was prepared by the action of dry chlorine on amorphous phosphorus and distillation after the chlorine had been displaced by carbon di-oxide. The portion distilling between 76° and 78° only was used. The number is the mean of the results; extreme difference, 0.08. Ag = 108; Cl = 35.5. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 172.)

PLATINUM.

Regnault and Kopp have determined the specific heat of platinum. It answers to an atomic weight of about 197. (*Gmelin-Kraut*, *l. c.*)

J. J. BERZELIUS: *197.19* (O = 16).

Determined by the same method as osmium, q. v., from a single experiment on potassium auroplatinate. 2.135 potassium chloride accompanied 2.822 platinum. [If KCl = 74.594 (Stas,) this gives the above value.] The salt was prepared by precipitating an alcoholic solution of platinum chloride with potassium chloride, washing with alcohol and heating to redness in a current of chlorine. Berzelius remarks that the metal used in his former determinations was impure. (*Poggend. Ann.*, *13*, 1828, 468, and *Lehrbuch*, *3*, 1213.)

T. ANDREWS: 197.88 (O = 16).

Determined by three experiments on potassium chloroplatinate. The salt was dried at 105° in vacuo, decomposed by zinc, the excess of zinc removed by acetic acid, the solution filtered off, and the chlorine titrated. The number is the mean; extreme difference, 0.22. The values assumed for Ag and Cl are not given. They were most likely Marignac's. (*Brit. Assoc. Rep.*, 1852, part 2, 33.)

J. S. Stas made preparations for determining the atomic weight of platinum, but not being able to produce potassium chloroplatinate entirely free from water, and being unacquainted with Bunsen's method of accomplishing this end, resigned the attempt. He made, indeed, three analyses by the same method employed by Berzelius, but unfortunately does not communicate the results. (*Stas*, *Untersuch. über Chem. Prop.*, *Leipzig*, 1867, 265.)

POTASSIUM.

Regnault determined the specific heat of potassium. It corresponds to an atomic weight of about 39. (*Gmelin-Kraut*, *l. c.*)

M. H. KLAPROTH; F. H. WOLLASTON: *39.517* (O = 16).

Klaproth found that 441 Cl = 591 potassium oxide. Hence Wollaston deduced the value 491 (O = 100) for K. [If Cl = 35.457, this relation gives K = 39.517.] (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *39.193* (O = 16); 244.958 (O = 100).

Berzelius found that 100 KCl = 192.4 Ag Cl. If Ag = 1351.607; Cl = 442.65; the above value follows. (*Poggend. Ann.*, *8*, 1826, 190.)

F. PENNY: 39.073 (O = 16).

Penny made six experiments on the conversion of the chlorate into the chloride. Potassic chlorate was dried at about 105°, dissolved in a flask with HCl, evaporated, dried and weighed. The cake contained some free HCl. It was broken up, pulverized, and a known quantity heated to dull redness but not to fusion, and the HCl expelled allowed for. The mean result was that 100 KCl O_3 = 60.823 KCl; extreme difference, 0.015. This relation gives KCl = 74.527 and if Cl = 35.454 (Penny,) the value for K follows. Numerous experiments were also made on the introconversion of the nitrate, the chloride and the chlorate, which established the difference between a chloride and a nitrate, besides confirming the value of K. The salts were purified by recrystallization and were carefully tested for impurities. The weighings are all for vacuum. (*Phil. Trans.*, *129*, 1839, 18.)

C. MARIGNAC: *39.2* (O = 16); 245 (O = 100).

By six experiments on the decomposition of the chlorate by heat, 100 chlorate were found to lose 39.161 oxygen; extreme difference 0.012; hence KCl = 932.14. By comparing this value with the molecular weight and the composition of argentic chloride, Cl was calculated at 442.13, leaving for K the number 490. Confirmatory experiments were made on potassic perchloride. The chlorate was purified by recrystallization. The weighings are for vacuum. (*Liebig's Ann.*, *44*, 1842, 23.)

476341

C. MARIGNAC: *39.115* (O = 16); 244.47 (O = 100).

Having determined the atomic weight of chlorine from syntheses of argentic chloride, and found it 443.2, the molecular weight of KCl in the last determination, gives K = 244.47, for vacuum. Berzelius, by rejecting some analyses and the correction for vacuum, deduces the value 244.429. (*Berzelius' Jahresbericht*, *25*, 1845, 31; *Bibl. Univ. de Genève*, *46*, 1842, 350.)

J. PELOUZE: *39.144* (O = 16); 244.65 (O = 100).

A known weight of KCl was brought into contact with a known amount of silver dissolved in nitric acid, the chloride being slightly in excess. This excess was titrated with a decimal solution of silver. The number is the mean of three experiments. Ag = 1349.01; Cl = 443.2. The chloride was prepared by heating the chlorate and recrystallizing the residue. (*Paris Comptes Rend.*, *20*, 1845, 1047.)

According to Pelouze, Levol found the molecular weight of KCl 466.245, which combined with Marignac's value of Cl would give K = 244.645 or *39.143*. (*Ibid.*)

E. J. MAUMENÉ: *38.96* (O = 16); 243.502 (O = 100.)

The mean of three experiments on the decomposition of KCl with an excess of argentic nitrate showed that 100 KCl = 192.75 AgCl. If Ag = 1350.32 and Cl = 443.67, according to Maumené's determinations, the number follows. The KCl was prepared from the chlorate by heat. To confirm his values for K and Cl, he made seven experiments on the decomposition of the chlorate by heat, and found that 100 chlorate gave 60.791 chloride. An unaccounted for increase in the weight of the flask occurred in these experiments. (*Annal. de Chim. et de Phys.*, (3,) *18*, 1846, 41.)

J. S. STAS: 39.137 (O = 16).

According to the mean of seven determinations, 100 parts of KCl dissolved in nitric acid, and evaporated to dryness give 135.6423 parts of nitrate; extreme difference, 0.017. If Cl = 35.457; N = 14.044; the value follows. This value is confirmed by previous experiments which gave 39.130. Potassic chloride, by whatever means it is prepared, still retains silica. Stas, therefore, determined

the amount of silica in the KCl and allowed for it. Weighings for vacuum. (*Stas, Untersuch. über Chem. Prop., Leipzig*, 1867.)

Stas mentions that Dumas, who was the first to place K at 39, afterwards became convinced that this number was too low. (*Ibid*, page 318.)

RHODIUM.

Regnault has determined the specific heat of rhodium. It corresponds to an atomic weight of about 104. (*Gmelin-Kraut, l. c.*)

J. J. Berzelius: *104.3* (O =16).

Berzelius made two analyses of dipotassic chlororhodiate. This salt can be completely desiccated in a current of chlorine at a red heat without decomposition. 3.146 grammes gave on reduction in a current of hydrogen 0.930 Cl, and the residue contained 1.304 KCl and 0.912 metallic rhodium. [If KCl = 74.594, Cl = 35.457, (Stas,) the atomic weight of the salt calculated from the Cl contents is 359.831, and that of Rh 104.272. The relation between the Rh and the Cl gives Rh =104.312. The relation between the KCl and the Rh gives Rh = 104.340. The mean is 104.308.] Berzelius made a second analysis of the crystallized salt in which he determined the water of crystallization. [Under the same suppositions and in the same order, the resulting values for Rh are 106.279; 104.762; 103.708.] In the *Lehrbuch* only the former analysis is used to deduce the atomic weight. Rhodium was separated from other metals by its insolubility in aqua regia. The double salt was formed by heating finely pulverized Rh in mixture with KCl in a current of chlorine. The double salt was dissolved in water, precipitated with alcohol, washed with alcohol and dried. (*Poggend Ann.*, *13*, 1828, 437; *Kongl. Vetens. Akad. Handl.*, 1828.)

In his earlier determination (Rh = 750.68 for O = 100) Berzelius mistook an hydrated oxide for a chloride. (*Ibid.*)

RUBIDIUM.

Kopp determined the specific heat of rubidium chloride. It corresponds to an atomic weight of about 85. (*Gmelin-Kraut, l. c.*)

KIRCHHOFF and BUNSEN: 85.36 (O = 16).

Determined from the mean of four experiments on the precipitation of the chloride with argentic nitrate. The extreme difference was 0.24. Ag = 107.94; Cl = 35.46. An impure mixture of rubidium and potassium chlorides, nearly free from lithium and the earths, was partially precipitated with platinum chloride and the precipitate freed from KCl by repeated boiling with water. The residue was reduced in a current of hydrogen, the rubidium chloride extracted with water, and reprecipitated with platinum chloride. This process was repeated until the potassium lines in the spectrum disappeared. The rubidium was then converted into a mixture of carbonate and oxide, and the caesium separated by extraction with alcohol. The amount of silver precipitated was also tested from time to time and the purification continued till this became constant. (*Poggend. Ann.*, *113*, 1861, 339.)

J. PICCARD: 85.41 (O = 16).

Determined by four analyses of rubidium chloride with argentic nitrate. The number is the mean; extreme difference, 0.09. The separation of potassium from rubidium was effected for the different analyses by 6, 7, and 8 successive partial precipitations with platinum chloride, and the separation of caesium by thirty successive extractions of the anhydrous carbonates with warm absolute alcohol. The salt analysed was spectroscopically pure. Ag = 107.94; Cl = 35.46. The experiments were made with Bunsen's assistance. (*Erdmann's Journ. für Prak. Chem.*, *86*, 1862, 449.)

L. Grandeau, who is sometimes credited with making a determination of Rb, expressly disclaims doing so. He mentions Bunsen's value as the true atomic weight and says that his analyses of the sulphate, undertaken to test its purity, led him to adopt the number 85.4; apparently for brevity's sake. (*Annal. de Chim. et de Phys.*, (3,) *67*, 1863, 227.)

R. GODEFFROY: 85.476 (O = 16).

Determined by four analyses of rubidium chloride prepared and analysed exactly as Godeffroy determined cæsium, q. v.; extreme difference, 0.04. Cl = 35.5; Ag = 108. (*Liebig's Ann.*, *181*, 1877, 189.)

RUTHENIUM.

Bunsen has determined the specific heat of ruthenium. It corresponds to an atomic weight of about 104. (*Gmelin-Kraut, l. c.*)

C. E. CLAUS: *104.57* (O = 16).

Determined from three analyses of potassium chlororutheniate by the same method Berzelius had employed for other platinum metals. Claus found an average of 28.783 per cent. Ru; extreme difference 0.48, and 41.063 KCl; extreme difference, 0.51. [If K = 39.137, Cl = 35.457; this composition gives Ru = 104.57. The weighings as given in the memoir are misprinted.] Claus also determined the chlorine with silver; the results were such as to show that the salt was not anhydrous, though it had been dried at 200° in an atmosphere of Cl. The salt was prepared by the evaporation of a solution of ruthenium and potassic hydrate in aqua regia, solution of other chlorides of Ru in dilute HCl, and removal of basic compounds by mechanical concentration in water. Claus later takes the atomic weight of Ru = 104. In this memoir he puts it at 651.387 (O = 100,) *104.22* (O = 16,) without mentioning the values of K and Cl. (*Poggend. Ann.*, *65*, 1845, 218.)

SELENIUM.

Regnault determined the specific heat of selenium, which accords with an atomic weight of about 79. (*Gmelin-Kraut, l. c.*)

J. J. BERZELIUS: *79.23* (O = 16).

Berzelius found that 100 Se absorb 179 dry chlorine gas, and that the product was exactly decomposed by water into chlorhydric acid and selenious acid. [If Cl = 35.457 (Stas) the value follows.] (*Poggend. Ann.*, *8*, 1826, 21.)

F. SACC: *78.55* (O = 16); 490.93 (O = 100).

Sacc's experiments are very discordant. He made three experiments on the reduction of a known weight of selenious acid with ammonium bisulphite and chlorhydric acid. The mean result was Se = 490.38; extreme difference, 5.5. In four experiments barium seleniate was decomposed by heating to redness with sulphuric acid in excess. The salt was found to contain 41.95 selenious acid; extreme difference 0.04. For Ba = 856.877 the resulting value is 491.49. The selenium was purified by solution in nitric acid, evaporation and sublimation, and by reduction with HCl and ammonium bisulphite. Selenious acid was prepared by oxidation with nitric acid. Barium seleniate was prepared by precipitation of barium nitrate with sodium seleniate and heating to redness. Sacc regards 490.3 as the most probable value of Se. (*Annal. de Chim. et de Phys.*, (3,) *31*, 1851, 119.)

A. SCHROETTER: 78.6 (O = 16).

Details not given. (*Kopp's Jahresbericht*, *4*, 1851, 318; *Sitz.-Bericht der k. k. Acad.*, *6*, 1851, 214.)

ERDMANN AND MARCHAND: 78.6 (O = 16); 492.5 (O = 100).

Determined from experiments on mercuric selenide by the same methods employed for the determination of S, q. v. Three experiments gave 71.726, 71.731, 71.741, per cent. mercury. (*Erdmann's Journ. für Prak. Chem.*, *55*, 1852, 202.)

J. DUMAS: 76.46 (O = 16).

Determined by seven experiments on the chloridation of selenium. The chloride was condensed in a tube cooled to — 20°, after which the escaping gases were led through other tubes filled with asbestos. The extreme difference in the results was 0.46. Cl = 35.5. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

O. PETTERSSON and G. EKMAN: 79.08 (O = 16).

Determined by five analyses of selenious acid. A warm solution of the acid was acidified with chlorhydric acid, precipitated with sulphurous acid and the selenium collected on a glass filter. Many precautions are necessary in the precipitation and drying. The value is the mean; extreme difference, 0.04. (*Berlin, Bericht der Chem. Gesell.*, *9*, 1876, 1212; *in extenso* in the *Acta of the Scientific Soc. of Upsala.*)

SILICON.

The vexed question of the composition of silicic acid has been settled by H. F. Weber, who found that the specific heat of this element becomes nearly constant above 200° and that the atomic heat is 5.8 for Si = 28. (*Poggend. Ann.*, *154*, 1875, 575.)

J. J. BERZELIUS: *29.63* (O = 16); *185.19* (O = 100).

100 parts of silicon, which had been heated to redness, and freed from silicic acid by hydrofluoric acid, gave 208 parts silicic acid, whence the value. Berzelius also made analyses of barium fluosilicide from which he calculated the oxygen contents of the acid at 51.975. This gives for the atomic weight of Si *29.58*. (*Poggend. Ann.*, *8*, 1826, 20; and *Lehrbuch*, *3*, 1200.)

J. PELOUZE: *28.46* (O = 16); 177.88 (O = 100).

A known weight of perfectly pure silver, dissolved in nitric acid, was brought in contact with a known and slightly excessive weight of silicon tetrachloride and the excess titrated with decimal silver solution. The value is derived from the mean of two experiments; difference 0.76 for O = 100; Cl = 443.2, Ag = 1349.01. The chloride was prepared by Ebelmen; it was perfectly transparent, volatilized without residue, and had been dried for a long time in a vacuum. (*Paris, Comptes Rend.*, *20*, 1845, 1047.)

J. DUMAS: 28.02 (O = 16).

Determined from the mean of two experiments on the tetrachloride which was weighed off in a glass bulb and

introduced, so enclosed, into a vessel containing water. The bulb was broken and the chlorine contents titrated with argentic nitrate. The difference between the experiments was 0.2 for O = 16, Ag = 108, Cl = 35.5. The chloride was repeatedly rectified; its boiling point was 59°. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

J. SCHIEL: 28.01 (O = 16).

Determined by two analyses of the tetrachloride. The salt was decomposed with a slight excess of ammonium hydrate and the chlorine titrated with argentic nitrate. The atomic weights of Cl and Ag used are not stated. Schiel found 0.6738 silicic chloride = 2.277 argentic chloride, and 1.3092 silicic chloride = 4.418 argentic chloride. [For Ag = 107.93, Cl = 35.457, these data give Si = 28.13, and 27.89.] (*Liebig's Ann.*, *120*, 1861, 94.)

SILVER.

Dulong and Petit, Regnault and others have determined the specific heat of silver and found it in accord with an atomic weight of about 108. (*Gmelin-Kraut, l. c.*)

MARCET; DAVY; WENZEL; WOLLASTON.

Wollaston in his table of equivalents mentions that Marcet found 441 Cl = 1350 silver, and Davy the same quantity of chlorine = 1360 silver. Wenzel found 200 sulphur = 1360 silver. (*Phil. Trans.*, *104*, 1814, 21.)

J. J. BERZELIUS: *108.129* (O = 16); 675.804 (O = 100).

Berzelius found that 100 silver gave 132.75 argentic chloride. Taking Cl = 221.325 he calculates Ag = 1351.607. He expresses uncertainty whether or no this value should not be reduced to one half. (*Poggend. Ann.*, *8*, 1826, 180.)

E. TURNER: 108 (O = 16).

Turner determined the composition of argentic chloride at 100 silver to 132.8 chloride. These numbers are for

vacuum. If Cl = 35.42 (Turner) the value follows. (*Phil. Trans.*, *123*, 1833, 536.)

F. PENNY: 107.97 (O = 16).

Penny made six experiments on the conversion of silver into nitrate. The silver was dissolved in cold nitric acid, the solution evaporated, and the nitrate fused all in one flask and with precautions against loss by spiriting. He found 100 Ag = 157.441 nitrate; extreme difference, 0.028. In five experiments the nitrate from the preceding determinations was converted into chloride, by means of chlorhydric acid, in the same flask, dried, fused, and weighed. Penny could detect no decomposition in fusion. He found 100 Ag = 132.8372 chloride; extreme difference, 0.01. In two experiments silver was dissolved in nitric acid, precipitated with chlorhydric acid, evaporated and fused, giving 132.830 and 132.838. The mean of all seven experiments is 132.836. Penny takes 132.837. From the relations of the chlorides, chlorates, and nitrates of potassium and sodium, Penny had determined the difference between the atomic weights of a chloride and a nitrate at 26.565. This gives the molecular weight of argentic chloride at 143.424 and Ag = 107.97. The silver used, as well as the water and the acids, were carefully tested for impurities and a minute amount of solid residue in the twice distilled water and in the acids was allowed for. The weighings were all reduced to vacuum. (*Phil. Trans.*, *129*, 1839, 27.)

C. MARIGNAC: *108* (O = 16); 675 (O = 100).

Silver was dissolved in nitric acid and precipitated with chlorhydric acid. One experiment, reduced to vacuum, gave 100 silver = 132.74 chloride, which Marignac considered confirmatory of Berzelius' value, 132.75. He therefore adopted the latter number. 100 potassic chloride were found to produce 192.26 argentic chloride, in two experiments, the difference between which was 0.01. By analysis, by means of heat, of potassic chlorate, Marignac had found the molecular weight of the chloride 932.14, these relations give the molecular weight of argentic chloride at 1792.13 and the atomic weight of silver at 1350. The potassic chloride was prepared by heating the chlorate and cooling the resulting chloride over sulphuric acid. (*Liebig's Ann.*, *44*, 1842, 23.)

C. MARIGNAC: *107.922* (O = 16); 674.505 (O = 100).

Marignac redetermined the relation between silver and potassic chloride by Pelouze's method. He found 100 Ag = 69.062 KCl in six experiments, the extreme difference between which was 0.018. In five experiments he found 100 KCl = 192.348 Ag; extreme difference 0.04. He also redetermined the composition of argentic chloride. The silver was dissolved in a long-necked flask and the fumes passed into a second flask containing water. Solution being effected, the water from the second flask was added to the contents of the first, and the whole precipitated with HCl. The chloride was washed, dried, melted and weighed in the same flask. The result was 100 Ag = 132.84 chloride; extreme difference 0.019. Combination of these data with Marignac's old value for the molecular weight of KCl, 932.14, gives Ag = 1349.01. All weighings reduced to vacuum. Berzelius revised the result by throwing out one experiment and by rejecting the correction for vacuum. He thus got Ag = 1349.66. (*Berzelius' Jahresbericht*, *24*, 58; *25*, 31; *Bibl. Univ. de Genève*, *46*, 1842, 350.)

In opposition to Prout's hypothesis, Marignac cites his analyses of argentic acetate, in which the escaping gases were forced to pass over porous silver. They gave in three experiments 64.664 silver from 100 acetate; extreme difference 0.005. If C = 75, this gives Ag = 1349.6. He also found 100 Ag = 157.455 nitrate. [If N = 87.5, this gives Ag = 1348.88.] He also found 100 Ag = 49.556 ammonium chloride. (*Liebig's Ann.*, *59*, 284; *Bibl. Univ. de Genève*, 1846.)

LIEBIG and REDTENBACHER; STRECKER: *107.903* (O = 16); 674.395 (O = 100).

Strecker recalculated Liebig and Redtenbacher's analyses of argentic acetate, tartrate, racemate and malate by the method of least squares, and from the difference in the atomic composition of these salts. He obtained for Ag the value 1348.79. *Vide* Carbon. (*Liebig's Ann.*, *59*, 1846, 280.)

E. J. MAUMENÉ: *108.026* (O = 16); 675.16 (O = 100).

In four experiments argentic oxalate was mixed with sand in a flask and decomposed by heat in a current of air. The

products of decomposition were passed over cupric oxide, and through drying tubes and potash tubes. In five experiments the acetate was treated in the same way, but not mixed with sand. The mean result was Ag = 1350.32; extreme difference 0.77. Maumené found it very difficult to purify the oxalate, which showed traces of nitric acid after 100 washings. (*Annal. de Chim. et de Phys.*, (3,) *18*, 1846, 41.)

J. S. Stas: 107.93 (O = 16).

Thirteen syntheses of argentic iodide, performed by bringing hydroiodic acid in contact with argentic sulphate or nitrate, gave 100 Ag = 117.5343 iodine. Three analyses of argentic iodate, performed by decomposition by heat in a current of nitrogen or by reduction of the salt, while in suspension, by a current of sulphurous anhydride, gave AgI = 234.779. Hence Ag = 107.928. Four syntheses of the bromide, performed by bringing hydrobromic acid in contact with argentic sulphate, gave 100 Ag = 74.0805 Br. Two analyses of argentic bromate, by reduction while in suspension with sulphurous anhydride, gave Ag Br = 187.87. Hence, Ag = 107.921. Seven syntheses of argentic chloride, three of them by combustion of silver in chlorine, three by precipitation with HCl, and one by precipitation with ammonium chloride, gave 100 Ag = 32.8445 Cl. Stas adopts the number 32.85 on the supposition that no excess of chlorine was possible. The chloride was fused. Two analyses of the chlorate, accomplished by heat or by evaporation with chlorhydric acid, gave Ag Cl = 143.395. Hence Ag = 107.937. Five syntheses of the sulphide, performed by heating silver in a current of sulphur vapor, or of hydrogen sulphide, gave 100 Ag = 114.8522 argentic sulphide. Six analyses of the sulphate by reduction in a current of hydrogen, showed that 100 sulphate contained 69.203 silver, hence Ag =107.920, [107.926? *vide* Sulphur.] From analysis of potassium chlorate, Stas had determined the molecular weight of KCl at 74.59. By twenty-four determinations he found 100 Ag = 69.103 KCl, hence Ag = 107.943. The silver was prepared either by Levol's method or by decomposing an ammoniacal solution of argentic nitrate with a mixture of ammonium sulphite and a copper salt. The metal was heated to the boiling point until the sodium line disappeared and the metallic fumes were a pale blue. To test its purity, it was compared with distilled silver. See Stas's determinations of Cl, Br, I, S,

and K. All weighings reduced to vacuum. (*Stas, Untersuch. über Chem. Prop., Leipzig*, 1867.)

SODIUM.

The specific heat of sodium has been determined by Regnault and indicates an atomic weight of about 23. (*Gmelin-Kraut, l. c.*)

H. DAVY; F. H. WOLLASTON: *23.28* (O = 16); 145.5 (O = 100).

Davy found that 134 Cl combine with 88 Na to form sodium chloride. If Cl = 441, the value follows. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *23.164* (O = 16).

Berzelius found that 100 Na Cl = 244.6 Ag Cl. [If Ag Cl = 143.387, (Stas,) the value follows.] (*Poggend. Ann.*, *8*, 1826, 189.)

F. PENNY: 23.046 (O = 16).

Penny made four experiments on the conversion of the chlorate into the chloride by means of HCl. A known weight of the salt was dissolved in a flask in the acid and evaporated, dried and weighed without removal. The sodium chloride was not fused. The mean result was that 100 chlorate equals 54.930 chloride; extreme difference, 0.02. This relation gives the molecular weight of the chloride at 58.5. Penny had found the atomic weight of Cl = 35.454; hence the value for Na. [If Cl = 35.457 (Stas,) Na = 23.043. Stas himself found 23.043.] The sodium chlorate was prepared by precipitating potassium chlorate with sodium bitartrate, and purifying the sodium chlorate by recrystallization. The weighings are for vacuum. (*Phil. Trans.*, *129*, 1839, 25.)

J. PELOUZE: *22.97* (O = 16); 143.59 (O =100).

A known weight of perfectly pure silver was dissolved in nitric acid, and brought in contact with a known and

slightly excessive weight of sodium chloride, and the excess titrated with decimal silver solution. The mean result of three experiments was that 100 Ag = 51.141 Na Cl; extreme difference, 0.033. The value follows for Ag = 1349.01; Cl = 443.2. The sodium chloride was prepared either from sodium sulphate and barium chloride, or from sodium carbonate and chlorhydric acid, or from a very pure rock salt. It was repeatedly recrystallized and was dried at 200° or melted. (*Paris Comptes Rend.*, *20*, 1845, 1047.)

J. DUMAS: 23.011 (O = 16).

Determined from the mean of seven experiments on the titration of sodium chloride with argentic nitrate; extreme difference, 0.09. Ag = 108; Cl = 35.5 [Dumas gives the mean as 23.014 instead of 23.0114.] For five experiments Na Cl recrystallized ten times and melted was employed. For two experiments (giving an average of 23.036) the residue from the incineration of the acetate was used to prepare Na Cl, which was recrystallized four times and melted. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

J. S. STAS: 23.043 (O = 16).

According to the mean of 10 determinations 100 Ag = 54.2078 Na Cl; extreme difference 0.0033. The sodium chloride was found to contain a minute quantity of silicic acid which reduces the result from Na = 23.049 to 23.045 for Ag = 107.93; Cl = 35.457. According to the mean of five determinations 100 Na Cl = 145.4526 sodium nitrate; extreme difference 0.025. If N = 14.044 this gives Na = 23.045. The lowest determination gives Na = 23.042. The sodium chloride was purified by recrystallization and in part by conversion into sodium chloroplatinate. The weighings are for vacuum. (*Stas, Untersuch. über Chem. Prop., Leipzig*, 1867.)

STRONTIUM.

Regnault determined the specific heat of strontium chloride. It corresponds to an atomic weight of about 87.5. (*Gmelin-Kraut, l. c.*)

M. H. KLAPROTH; F. H. WOLLASTON: *94.4* (O = 16); 590 (O = 100).

Klaproth found 42 sulphuric anhydride = 58 strontium oxide; whence the value for S = 200. (*Phil. Trans.*, *104*, 1814, 20.)

F. STROMEYER; *87.34* (O = 16); 545.929 (O = 100).

According to Berzelius, Stromeyer found that 100 strontium chloride = 181.25 argentic chloride; whence the value, for Ag = 1349.66; Cl = 221.64. (*Berzelius' Lehrbuch*, *3*, 1229.) In *Gilbert's Ann.*, *54*, 1816, 251, Stromeyer refers to this analysis as by V. Rose. Stromeyer himself found 0.5 grm. carbonate = 75.5394 c. c. carbon di-oxide [which gives Sr = 88.26 if 1000 c. c. carbon di-oxide weigh 1.96433 grm.] Stromeyer calculated Sr = 552.28 for O = 100.

—. SALVETAT: 88 (O = 16); 550 (O = 100).

Determined from the loss of weight of strontium carbonate by calcination and on driving off carbon di-oxide with sulphuric acid. Details not given. (*Paris Comptes Rend.*, *17*, 1843, 318.)

J. PELOUZE: *87.68* (O = 16); 548.02 (O = 100).

A known weight of perfectly pure silver was brought in contact with a known and slightly excessive amount of strontium chloride and the excess titrated with decimal silver solution. The number is the mean of two experiments; extreme difference, 0.2. Ag = 1349.01; Cl = 443.2. The chloride was purified by recrystallization and was dried at 200° or below redness. (*Paris Comptes Rend.*, *20*, 1047.)

C. MARIGNAC: 87.54 (O = 16).

Marignac made experiments on three different preparations of strontium chloride, (1,) (2,) (3.) Compared with silver by Pelouze's method it was found that ten grammes strontium chloride = (1) 8.103; (2) 8.099; (3) 8.101 silver. The same strontium chloride converted into sulphate gave (1) 6.887; (2) 6.8855; (3) 6.884 sulphate. In both these series of experiments the strontium was weighed as air-dried, hydrous, crystalline chloride. Comparison gives Sr

= (1) 43.79; (2) 43.82; (3) 43.77. In each experiment of the latter series the water was determined by driving it off at a red heat. It was proved that the chloride does not undergo decomposition at this temperature, and the water contents was found to vary no more than 0.0005 of the total weight. In three more experiments the water was determined, and the anhydrous salt analysed by Pelouze's method giving (1) 43.77; (2) 43.74; (3) 43.76. Ag = 108; Cl = 35.5; S = 16. The chloride was prepared (1) from the chemically pure chloride of commerce by precipitating barium with sulphuric acid, separation of lime by precipitation of the strontium chloride by HCl gas and washing with chlorhydric acid. The purity was tested by the solubility of a portion converted into sulphate. The chloride was finally redissolved and precipitated with alcohol. (2) was prepared from (1) by a repetition of the same process. (3) was prepared from (2) by recrystallization. (*Bibl. Univ., Arch. des Sciences*, (2,) *1*, 1858, 220.)

J. Dumas: 87.52 (O = 16).

Determined from the mean of six experiments on the analysis of strontium chloride with argentic nitrate. The extreme difference was 0.14, Cl = 35.5; Ag = 108. The salt was purified by boiling with sulphuric acid, and precipitation with and recrystallization from chlorhydric acid. These processes were in some cases several times repeated. The pure salt was fused in a current of HCl gas. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

SULPHUR.

Deville and Troost and others have determined the density of sulphur in the gaseous form. It corresponds to an atomic weight of about 32. The specific heat of sulphur also agrees moderately well with this value. (*Gmelin-Kraut, l. c.; L. Meyer, l. c.*)

J. J. Berzelius; F. H. Wollaston: *32* (O = 16); 200 (O = 100).

According to Wollaston, Berzelius found that plumbic sulphide was composed of 86.64 lead and 13.36 S. Hence the value, for lead = 1295. (*Phil. Trans.*, *104*, 1814, 20.)

J. J. BERZELIUS: *32.19* (O = 16) 201.165 (O = 100).

A known weight of lead was dissolved in pure nitric acid, precipitated with sulphuric acid and evaporated. The mean result of four experiments was that 100 Pb = 146.44 sulphate. The variation was only in the fifth figure. If lead = 1294.498 the value follows. [If this relation is recalculated with Stas's atomic weight of lead, S = 32.096.] (*Poggend. Ann. 8*, 1826, 16.)

E. TURNER: 32.17 (O = 16).

Determined from syntheses of plumbic and baric sulphates. The former gave 16.083, the latter, 16.087. Ba = 68.7, Pb = 103.6. The numbers are for vacuum. *Vide* Barium and Lead. (*Phil. Trans.*, *123*, 1833, 539.)

T. THOMSON: *32* (O = 16); 200 (O = 100).

This chemist found the specific gravity of sulphurous acid in mean of two experiments, 2.22216, almost exactly double 1.1111 which he takes (on utterly untenable grounds) for the specific gravity of oxygen. (*Erdmann's Journ. für Prak. Chem.*, *8*, 1836, 370; *Records of General Science by R. D. Thomson*, 1836, 179.)

ERDMANN and MARCHAND: *32.004* (O = 16); 200.026 (O = 100).

Determined by four experiments on the decomposition of mercuric sulphide by copper, in a current of carbon dioxide, the mercury being caught in a cold receiver. The mean composition was found to be for vacuum 86.211 mercury and 13.789 sulphur, extreme difference, 0.017 Hg. If Hg = 1250.6, the value follows. In purifying the sulphide it was first heated to drive off excess of sulphur and then sublimed three times, the first and last portions of the sublimate being rejected. (*Erdmann's Journ. für Prak. Chem.*, *31*, 1844, 396.)

J. J. BERZELIUS: *32.12* (O = 16); 200.75 (O = 100).

Berzelius' former value, 201.165, is changed by the new value for lead, 1294.645 to 200.8017. Three new experiments were made by gently heating argentic chloride in a current of hydrogen disulphide. The mean of three experiments gives S = 200.706; extreme difference 0.11. Cl = 443.38, Ag = 1349.66. (*Berzelius' Jahresbericht*, *25*, 1845, 37, and *Lehrbuch*, *3*, 1185.)

H. STRUVE: 32.002 (O = 16).

Determined by six experiments on the reduction of a known weight of argentic sulphate in a current of hydrogen. The number is the mean; extreme difference, 0.146. Ag = 108. The sulphate was prepared by precipitating the nitrate with an excess of sulphuric acid, and drying at a high temperature. (*Liebig's Ann.*, *80*, 1851, 203; *Berzelius' Jahresbericht*, *30*, 20.)

J. DUMAS: 32.0196 (O = 16).

Determined by five experiments on the combustion of silver in sulphur vapor. The number is the mean; extreme difference, 0.054. Ag = 108. The sulphur was purified by repeated distillation. The silver was heated to redness in a current of sulphur vapor, the excess of sulphur being afterwards distilled off in a current of carbon di-oxide. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 147.)

J. S. STAS: 32.0742 [?] (O = 16).

According to the mean of six analyses of argentic sulphate by decomposition in a current of hydrogen at as low a temperature as possible, 100 sulphate yield 69.203 [more exactly 69.20317] silver; extreme difference, 0.012. Five syntheses of the sulphide, performed by heating silver in a current of sulphur vapor or hydrogen disulphide, showed that 100 silver = 114.8522 sulphide; extreme difference, 0.005. By comparing these figures, which are for vacuum, Stas deduces S = 32.0742; Ag = 107.920. [There seems to be a trifling error in this calculation. The weighings seem to be correct, for the means correspond to the details given. As given, the numbers indicate S = 32.058; Ag = 107.926. The latter is almost identical with Stas's mean value, 107.930.] The sulphate was prepared by the action of sulphuric acid on argentic nitrate, or by solution of silver in sulphuric acid. The salt was heated above the boiling point of sulphuric acid. (*Stas, Unters. über Chem. Prop.*, *Leipzig*, 1867.)

TANTALIUM.

Deville and Troost have determined the vapor density of tantalium chloride. It agrees with an atomic weight of 182. (*Paris Comptes Rend.*, *64*, 1867, 294.)

J. J. BERZELIUS: *167.74* (O = 16).

Berzelius decomposed the sulphide in dry chlorine gas and decomposed the resulting chloride with water. 99.75 parts sulphide yielded 89.35 tantalic acid. On the supposition that the acid contains three atoms of oxygen Berzelius calculates the atomic weight at 1148.365 for S = 200.75. [If the acid contains five atoms of oxygen the value becomes 167.74.] (*Poggend. Ann.*, *4*, 1825, 14, and *Lehrbuch*, *3*, 1209.)

Rose denies that the sulphide formed, as Berzelius prepared it, by heating tantalium in carbon disulphide vapor is a constant compound. (*Poggend. Ann.*, *99*, 580.) Marignac, however, shows that Berzelius, Rose and Hermann, obtained constant results from its analysis, from 89.50 to 90 acid from 100 sulphide. If Ta = 182, the sulphide would give 90.24 acid. (*Liebig's Ann.*, *S*, *4*, 1866, 358.)

H. ROSE: *172* (O = 16).

Out of twelve analyses of the chloride, in which both the chlorine and the tantalic acid were determined, Rose selected two in which the agreement was best. [These analyses calculated for Ag = 107.93, Cl = 35.457, give Ta = 171.96.] The chloride was prepared from tantalic acid especially freed from tungsten and tin by mixing with carbon, drying in carbon di-oxide, and heating in a current of chlorine in which the salt was allowed to cool. Excess of chlorine was expelled by dry air, and the salt was hermetically sealed in glass. Rose supposed the acid to contain two atoms of oxygen and therefore deduces the value 859.81 (O = 100). (*Poggend. Ann.*, *99*, 1856, 75.)

Marignac seems to prove that the material with which Rose dealt contained niobium. He states that the chlorides of the two elements cannot be separated from one another, and that there are no characteristics by which their purity can be decided. (*Liebig's Ann.*, *S*, *4*, 1866, 352.)

R. HERMANN:

Hermann made many analyses of tantalium salts to which, however, he ascribes quite incomprehensible formulas. Marignac has shown that his methods were utterly inadequate to produce pure preparations. He assumes two atoms of tantalium and three atoms of oxygen in the acid and gives the atomic weight as 645. (O = 100.) (*Erdmann's Journ. für Prak. Chem.*, *70*, 1857, 193.)

C. MARIGNAC: 182 (O = 16).

Berzelius', Rose's and Marignac's analyses of the double fluoride of tantalium and potassium show that the fluorine is combined with Ta and potassium in proportions of two to five. The salt has also exactly the crystal form of the niobium salt. Hence the acid is a ditantalic pentoxide. Four experiments were made on this salt by drying at 100°, moistening with sulphuric acid and heating gradually till the excess of acid was driven off. The potassic sulphate was leached out, evaporated, melted and weighed, and the tantalic acid heated to redness and weighed. The mean potassic sulphate contents was found to be 44.29 per cent; extreme difference, 0.15. The mean amount of tantalic acid obtained was 56.59; extreme difference, 0.25. If K = 39, these data give Ta = 182.3. Four analyses were also made of the ammonium salt. This contained traces of potassium which were determined and allowed for in each case. The mean amount of tantalic acid obtained was 65.25 per cent; extreme difference, 0.34. This gives Ta = 182, the number which Marignac adopts. The salts were obtained by dissolving tantalic acid, which had not been heated to redness, in fluohydric acid, adding potassic or ammonic hydrate and purifying by recrystallization. These salts are much less soluble than the corresponding niobium and titanium salts. (*Liebig's Ann.*, *S. 4*, 1866, 234.)

TELLURIUM.

Regnault and Kopp have each determined the specific heat of tellurium and found it in accord with an atomic weight of about 128. (*Gmelin-Kraut*, *l. c.*)

J. J. BERZELIUS *129.03* (O = 16); 806.452 (O = 100).

A known weight of metallic tellurium was oxidized with nitric acid, the excess of acid being driven off by heat. It was found that 100 Te gave 124.8 tellurious acid. (*Poggend. Ann.*, *8*, 1826, 24.)

J. J. BERZELIUS: *128.28* (O = 16); 801.76 (O = 100).

Determined as before but with purer material. Three experiments were made, which gave 802.838, 801.786, 801.74. Berzelius took the mean of the latter two. The tellurium was prepared from tetradymite by heating with potassium carbonate and olive oil in a closed crucible, dissolving the potassium telluride so formed in water free from air, precipitating the tellurium by a current of air and distilling it in a current of hydrogen. (*Poggend. Ann.*, *32*, 1834, 16.)

K. VON HAUER: 128.06 (O = 16).

Determined from the mean of five experiments on the precipitation of bromine with argentic nitrate from the double bromide of potassium and tellurium. The bromine contents was found to be 69.9236 per cent., for Ag = 108.1; Br = 80; extreme difference 0.172. If K = 39.2, the value follows. The salt was prepared by mixing tellurium and potassic bromide in atomic proportions, adding water and bromine, heating to drive off excess of bromine and repeated recrystallization. (*Erdmann's Journ. für Prak. Chem.*, *73*, 1858, 98; *Sitz-Bericht der k. k. Acad.*)

J. DUMAS: 129 (O = 16).

No details are given. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 129.)

THALLIUM.

Regnault determined the specific heat of thallium. It agrees with an atomic weight of 204. (*Gmelin-Kraut, l. c.*)

A. LAMY: 204 (O = 16).

Three analyses of the chloride with argentic nitrate gave

a mean of 204; extreme difference 1.2. An experiment on the precipitation of the sulphate with barium nitrate gave 204.3. [The atomic weights used were probably those accepted by Dumas.] The salts were purified by recrystallization. (*Annal. de Chim. et de Phys.*, (3,) *67*, 1863, 411.)

W. Crookes: 202.96 (O = 16).

These determinations were made from the sulphate, which was prepared with great care. By decomposing the sulphate with potassic iodide and weighing the thallic iodide formed, the atomic weight was found at 202.73; by precipitation with barium nitrate, 203.55; with chlorhydric acid and alcohol, thallic chloride being weighed, 201.85; from the amount of sulphate produced from a known weight of metal, 203.1; by precipitation with platinum chloride, 203.56. The values taken for Cl, I, etc., are not given; [they were probably those accepted by Dumas.] (*Erdmann's Journ. für Prak. Chem.*, *92*, 1864, 277; *Chem. News.*)

H. Werther: 204 (O = 16).

In five experiments Werther decomposed thallic iodide with potassic hydrate and zinc, both perfectly pure, and precipitated the iodine with silver. The mean result of these experiments was Tl = 204.4; extreme difference 1.7. [The value assumed for I is not stated. One experiment, which gave exactly 204, according to Werther, recalculated for Ag = 107.93; I = 126.85 gives Tl = 203.63.] Three experiments were made by decomposing the iodide with ammoniacal solution of argentic nitrate and weighing the argentic iodide formed. These determinations gave Tl = 203.47; extreme difference 0.3. The preparation of the iodide is not given. (*Erdmann's Journ. für Prak. Chem.*, *92*, 1864, 136.)

M. Hebberling: 203.94 (O = 16).

Hebberling made three experiments on the sulphate by precipitation with barium chloride, which gave in mean Tl = 204.13; extreme difference 0.2. He also made two experiments on the chloride by precipitation with argentic nitrate. These gave 203.8 and 203.5. The atomic weights assumed are not stated. [If Ag = 107.93; Cl = 35.457; the first analysis of the chloride gives Tl = 203.44. The data for the second analysis are misprinted. If a probable correction of a single figure is made, the data give Tl =

203.026.] The salts were purified by recrystallization. (*Liebig's Ann.*, *134*, 1865, 11.)

W. CROOKES: *204.155* (O = 16).

Determined by experiments on the solution of metallic thallium in nitric acid and evaporation to dryness. The number is the mean of ten experiments; extreme difference, 0.038. The balance stood in a partial vacuum, and the weighings were made at two different pressures and calculated for vacuum. Very elaborate precautions were taken throughout. Crookes also mentions determinations made with barium nitrate, but gives no data. The thallium was prepared in seven different lots by the reduction of as many different salts which had been purified by recrystallization &c. The metal was fused in lime. The reagents were expecially prepared by methods similar to those of Stas. Crookes took N = 14.009, O = 15.96, and calculated for Tl the value 203.642. [If O = 16, the value becomes 204.155.] (*Phil. Trans.*, *163*, 1873, 277.)

THORIUM.

From the isomorphism existing between thorium, tin, and titanium, and from the similarity of thorium to zirconium, Delafontaine and Marignac believe the oxide to contain two atoms of oxygen. (*Liebig's Ann.*, *131*, 100.) Neither the specific heat of this element nor the vapor density of any of its compounds has been determined so far as I know.

J. J. BERZELIUS; *238* (O = 16); 1887.72 (O = 100).

From the sulphate, precipitated by heating a solution of the salt and redissolved in cold water, Berzelius got the values 748.493 and 735.713 by precipitating with barium chloride. He also analysed the double sulphate of potassium and thorium. From the relation between the sulphuric acid and the thorium oxide found, the atomic weight would seem to be 750.63, while the relation between the potassic sulphate obtained, and the amount of oxide gives 740.6. These numbers are calculated on the supposition that the oxide contains a single atom of oxygen. Ba =

855.29, S = 200.75, K = 488.856. (*Poggend. Ann.*, *16*, 1829, 398, and *Lehrbuch*, *3*, 1224.)

J. J. CHYDENIUS: 236.64 (O = 16).

This chemist analysed the sulphate, the double sulphate of potassium and thorium, the oxalate, the acetate and the formate, getting results which vary from 228.52 to 243.76. He averages with his own results analyses made by Berzelius and by Berlin, which, however, alter the result inappreciably. According to Delafontaine, the methods employed for purification are ineffectual. Chydenius assumes a single atom of oxygen in the oxide. (*Poggend. Ann.*, *119*, 1863, 55.)

N. J. BERLIN: 231.64 (O = 16).

Chydenius reports two analyses of the oxalate by Berlin which gave for thorium 57.87 and 57.95, or 231.48 and 231.80. (*Poggend. Ann.*, *119*, 1863, 56.)

M. DELAFONTAINE: 231.5 (O = 16).

Determined from analyses of the sulphate. Fourteen experiments on the decomposition of this salt, by the heat of a strong double-draught lamp, gave a mean of 52.51 per cent. oxide; extreme difference, 0.83. In three experiments the sulphur contents of the salt was determined by precipitation with barium chloride after the sulphate had been decomposed with ammonium oxalate. The mean amount of sulphuric anhydride so found was 31.92 per cent.; extreme difference, 0.78. Three experiments on the water contents gave 15.68 per cent; extreme difference, 0.21. The sum of these means is 100.11. The value of thorium was calculated from the relation of the oxide to the sulphuric anhydride for S = 32, Ba = 137. The salt was prepared from thorite and from orangite by decomposition with sulphuric acid and recrystallization of the sulphate with the help of heat. The purification was continued until the crystals and the mother liquor had exactly the same composition. Marignac assisted at this investigation. (*Liebig's Ann.*, *131*, 1864, 100.)

P. T. CLEVE: 233.88 (O = 16).

Cleve made six analyses of the anhydrous sulphate, getting in mean Th = 233.8; extreme difference, 1.36. From

analyses of the oxalate he got 233.97; extreme difference, 0.6. (*Kopp's Jahresbericht*, 1874, 261; *Bull. Soc. Chim.*, (2,) *21*, 116.)

TIN.

Regnault and Kopp have each determined the specific heat of tin. It agrees with an atomic weight of about 118. Dumas, Cahours and others have determined the vapor density of volatile tin compounds with a similar result. (*Gmelin-Kraut, l. c.; L. Meyer, l. c.*)

J. J. BERZELIUS; *117.647* (O = 16); 735.294 (O = 100).

Berzelius determined this value by oxidizing pure tin foil by means of nitric acid and weighing the oxide. He found 100 tin = 127.2 stannic acid. (*Poggend. Ann.*, *8*, 1826, 184.)

G. J. MULDER: 116.112 (O = 16); 725.7 (O = 100).

Two experiments were made by oxidizing tin with nitric acid, evaporating, drying, and heating to redness. They gave each 100 tin = 127.56 stannic acid; whence the value. All possible precautions are said to have been taken. The metal was prepared by the reduction of pure oxide with soot and a flux. (*Erdmann's Journ. für Prak. Chem.*, *48*, 1849, 35; *Scheikundige Onderzoek.*, 5. *Deel*, 260.)

C. L. VLAANDEREN: about 118. (O = 16).

Determined from experiments on the oxidation and reduction of tin and stannic acid in vessels of various materials. The experiments regarded as the most accurate were made on the reduction of the acid in a current of hydrogen in porcelain vessels. The acid had been heated in platinum. These experiments gave 59.04 and 59.12. Stannic acid heated in glass or porcelain was found to retain nitric acid. (*Kopp's Jahresbericht*, *11*, 1858, 138; *Mulder*, *Scheikundige Verh. en Onderzoek.*, 2. *Deel*, 150.)

J. DUMAS: 118.08 (O = 16).

Two experiments were made on the oxidation of pure tin by nitric acid. The stannic acid being heated white

hot in platinum vessels gave for the atomic weight 59.1 and 58.96. The tin employed was prepared from pure chloride. Two experiments on the titration of the chloride with argentic nitrate gave 59.06 and 59.03. Ag = 108, Cl = 35.5. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 156.)

TITANIUM.

The specific heat of titanic acid has been determined by Regnault and by Kopp, and indicates an atomic weight of about 50. Dumas determined the vapor density of the tetrachloride at 6.836. [If the molecular weight of O = 32, and if Cl = 35.457, this gives Ti = 56.025.] (*Gmelin-Kraut, l. c.*, and *Poggend. Ann.*, *9*, 1827, 441.)

H. Rose: *61.17* (O = 16).

Determined by roasting titanium sulphide and weighing the titanic acid formed. The highest result obtained was 1.017 sulphide from 0.757 acid. This result Rose adopted on the supposition that an excess was impossible. For S = 201.16 these data give Ti = *62.25* (O = 16); 389.1 (O = 100.) [If S = 32, Ti = 61.17.] The sulphide was prepared by heating titanic acid in a current of carbon disulphide. (*Gilbert's Ann.*, *73*, 1823, 135.)

Rose subsequently expressed the opinion that the sulphide employed in this analysis was impure, and contained undecomposed titanic acid, but afterwards came to the conclusion that it was perfectly pure, accounting for the variation of the results from those he obtained later by the theory that the sulphide and the oxide of this element, like those of tantalium, were entirely dissimilar compounds. Marignac has shown that tantalium sulphide is of normal constitution. (*Poggend. Ann.*, *99*, 1856, 576.)

H. Rose: 48.28 (O = 16).

Titanium chloride was decomposed with water, titanic acid precipitated by ammonic hydrate, and the chlorine precipitated from the filtrate with argentic nitrate. Taking Ag = 1351.607, Cl = 221.325; Rose calculated the chlorine contents in four experiments at from 74.43 to 74.53 per

cent; mean 74.46 and Ti at 303.686. According to Gmelin-Kraut, these analyses recalculated for Stas's values give Ti = 48.28. The chloride was prepared by the action of chlorine on a mixture of titanic acid and carbon, and was rectified four or five times over potassium and mercury. It was clear and developed no chlorine on decomposition with water. (*Poggend. Ann.*, *15*, 1829, 145.)

C. G. MOSANDER: *47.33* (O = 16); 295.81 (O = 100).

Mosander determined the oxygen contents of titanic acid at from 39.83 to 40.82 per cent.; mean 40.427. Mosander never described the method of analysis. [The oxygen contents was probably determined from the chloride, for the above data give Ti = 294.7, while Berzelius records the determination as having given 295.81.] (*Poggend. Ann.*, *19*, 1830, 212, and *Berzelius' Lehrbuch*, *3*, 1211.)

J. PIERRE: *50.36* (O = 16).

Determined by three experiments on the titration of the chloride with argentic nitrate by Pelouze's method. Pierre does not give the values taken for Cl and Ag. He calculates the atomic weight of Ti at 314.69. [If Ag = 107.93, Cl = 35.457; his data give Ti = 314.75 (O = 100); 50.36 (O = 16), with an extreme difference in the latter case of 0.08.] He made two other determinations giving lower results, but it was found that the chloride employed was slightly decomposed by contact with air. The chloride was prepared from artificial titanic acid which was free from iron, and was further purified by fractional distillation. (*Annal. de Chim. et de Phys.*, (3,) *20*, 1847, 257.)

A. DEMOLY: *56.512* (O = 16).

Determined by experiments on the tetrachloride. The salt was decomposed with water, the titanic acid precipitated by ammonic hydrate, and the chlorine precipitated in the filtrate, after the excess of ammonic hydrate had been volatilized and the solution acidified. Both precipitates were weighed. Demoly calculates the atomic weight of Ti at 350, without mentioning what values he accepted for silver and chlorine. [If Ag = 107.93, Cl = 35.457; the atomic weight, calculated from the argentic chloride, is 353.2 (O = 100); or 56.512 (O = 16), with an extreme difference in the three experiments of 0.88 for O = 16.] The chloride was prepared from rutile by preliminary conver-

sion into nitride, &c. It was purified by rectification over mercury and potassium. (*Liebig's Ann.*, *72*, 213; *Laurent and Gerhardt*, *Comptes Rend.*, 1849, 325.)

TUNGSTEN.

Regnault has determined the specific heat of tungsten, and Roscoe the vapor density of the chloride. These experiments place the atomic weight of tungsten at about 184. (*Gmelin-Kraut*, *l. c.*; *L. Meyer*, *l. c.*)

J. J. Berzelius: *189.26* (O = 16); 1183.355 (O = 100).

A weighed quantity of tungstic acid was reduced in a current of hydrogen, again weighed, then re-oxidized and reweighed. The number is the mean result of the two operations. The number is given in Berzelius' *Lehrbuch* as 1188.36 with the data, which are also given in *Poggend. Ann.*, *8*, 23. It is pointed out in *Graham-Otto* that this value must be misprinted, an observation which I have verified. (*Poggend. Ann.*, *4*, 1825, 152.)

Berzelius made an earlier determination than the foregoing by the oxidation of the sulphide, getting 1207. He points out the source of error in this experiment arising from the formation of irreducible sulphate. (*Berzelius' Jahresbericht*, *5*, 1825, 121.)

R. Schneider: 184.12 (O = 16); 1150.78 (O = 100).

Schneider made five experiments on the reduction of tungstic acid with hydrogen in a porcelain tube heated by a charcoal fire. These analyses gave the mean contents of the acid at 79.316 tungsten per hundred; extreme difference, 0.096. This composition corresponds to an atomic weight of 1150.39. He also made three experiments on the combustion of tungsten, getting a mean of 79.327 tungsten per 100 acid; extreme difference, 0.005, or an atomic weight of 1151.17. The value taken is the mean. The tungstic acid was prepared by decomposing ammonio-tungstic sulphide with chlorhydric acid, washing the precipitate with acid, solution in ammonia, reprecipitation with chlorhydric acid, and so on until a perfectly pure product was obtained. The tungstic acid was finally dried and

heated to redness. (*Erdmann's Journ. für Prak. Chem.*, *50*, 1850, 163.)

R. F. MARCHAND: *184.1* (O = 16); 1150.6 (O = 100).

Determined from two experiments on the reduction of tungstic acid in a current of hydrogen, and two experiments on the combustion of tungsten. These determinations were made in the same manner as and at the same time with Schneider's. The extreme difference was 3.5 for O = 100. (*Liebig's Ann.*, *77*, 1851, 263.)

J. B. VON BORCK: *183.816* (O = 16); 1148.85 (O = 100).

Determined by seven experiments on the reduction of tungstic acid at a white heat by hydrogen, and by two experiments on the combustion of tungsten. The number is the mean; extreme difference, 10.38 for O = 100. The tungstic acid was prepared from Wolframite by fusing the mineral with potassium carbonate, solution in water containing alcohol, precipitation with calcic chloride and decomposition of the calcic tungstate with chlorhydric acid. The tungstic acid so produced was converted into ammonium salt which, on decomposition, yields a compound free from iron and manganese. (*Erdmann's Journ. für Prak. Chem.*, *54*, 1851, 254.)

A. RICHE: 174 (O = 16).

This value was reached by five determinations of the amount of water produced by the reduction of tungstic acid in a current of hydrogen, which gave a mean of 87.07; extreme difference, 1.78. The tungstic acid was obtained by heating the ammonium salt, or by the decomposition of the oxychloride produced by heating tungstic acid and carbon in a current of chlorine. (*Annal. de Chim. et de Phys.*, (3,) *50*, 1857, 10.)

J. DUMAS: *184* (O = 16).

Dumas made six experiments on the reduction of tungstic acid in hydrogen at a high temperature in a nacelle of unglazed porcelain, and two experiments on the titration of the chloride with argentic nitrate. The extreme difference between the results was 0.69 for O = 8. The acid was pre-

pared by gently heating the ammonium salt in a muffle. (*Annal. de Chim. et de Phys.*, (3,) *55*, 1859, 144.)

F. A. BERNOULLI: 186.8 (O = 16); 1167.5 (O = 100).

Bernoulli made five experiments on the reduction of tungstic acid by hydrogen in a porcelain tube at a very high temperature, two experiments on the amount of water formed in reduction, and four experiments on the oxidation of tungsten. The mean result was W = 93.41; extreme difference, 0.75. [If experiment 9, in which oxidation seems to have taken place, is left out, the mean becomes 93.35; extreme difference, 0.18.] The tungstic acid was prepared from ammonium tungstate which had been boiled for several days with nitric acid. The tungstic acid was heated to redness. One part of it was green, another part yellow. The determinations from the different colored acids did not differ, and Bernoulli considers them isomeric modifications of the same compound. There appear to be misprints in the data given. (*Poggend. Ann.*, *111*, 1860, 599.)

C. SCHEIBLER: 184 (O = 16).

Scheibler reached this value by five determinations of the water contents (9 molecules) of barium metatungstate. From determinations of the barium and the tungsten in the same compound Scheibler reached other values, but he regards the water determination as the most trustworthy. (*Erdmann's Journ. für Prak. Chem.*, *83*, 1861, 328.)

E. ZETTNOW: 183.952 (O = 16).

Determined from analyses of ferrous tungstate and argentic tungstate. A known weight of ferrous tungstate was melted with sodium carbonate and the mass dissolved. The ferric hydrate was thoroughly washed, dissolved in chlorhydric acid, reduced to ferrous chloride with zinc of known composition, and titrated with potassic permanganate in several measured portions. Four such series of experiments were made, and gave a mean of 92.038 for W; extreme difference, 0.33. The ferrous tungstate was prepared by melting pure anhydrous sodium tungstate with ferrous chloride and sodium chloride, dissolving, separating impurities, crystallizing, washing the crystals with water, chlorhydric acid and sodium carbonate. The argen-

tic tungstate was decomposed with nitric acid and titrated with sodium chloride or decomposed with hot sodium chloride solution, the argentic chloride being weighed. Five experiments gave a mean of 91.915 for W; extreme difference, 0.13. The argentic tungstate was prepared by the precipitation of sodium tungstate with argentic nitrate, thorough washing and drying in yellow light. The permanganate solution was prepared according to Mohr and tested with ammonio-ferrous sulphate. Fe = 28, Ag = 108. (*Poggend. Ann.*, *130*, 1867, 30.)

H. E. Roscoe: 184.04 (O = 16).

Determined by reducing tungstic acid in a current of hydrogen, by reoxidizing the metal, and by reducing the chloride in a current of hydrogen, the chlorhydric acid being condensed and estimated as argentic chloride. In the experiments on the acid, that compound was reduced, and reoxidized three times with almost identical results. The mean of the second and third reductions of the same sample gave W = 183.84. In the experiments on the chloride, the chlorine and the tungsten were each determined, and gave a mean of 184.25 for Cl = 35.5. The tungstic acid was prepared by the decomposition of the chloride, washing and heating to redness in a platinum vessel. It was canary yellow. The chloride was prepared from pure tungsten. (*Liebig's Ann.*, *162*, 1872, 366.)

URANIUM.

No certainty exists as to the relation between the equivalent and the atomic weight of uranium. The latter is commonly accepted as about 120. Mendelejeff gives grounds for supposing it to be 240, (*Liebig's Ann.*, *S. 8*, 1871, 178,) and L. Meyer regards it as probably 180, a value which accords well with the specific heat of the black oxide as observed by Regnault. (*Gmelin-Kraut, l. c.*) For the purposes of this paper it seems best to retain the customary value.

J. A. Arfvedson: *128.6* (O = 16).

Determined by experiments on the reduction of uranoso-

uranic oxide and on the oxidation of uranous oxide. By combustion of uranous oxide in oxygen he found in two experiments that 100 oxide combined with 3.695 and with 3.73 oxygen. From the reduction of the green oxide he found that 100 uranous oxide combine with 3.67 oxygen. He deduces as the mean 3.688. Regarding uranous oxide as the metal, Arfvedson calculated the atomic weight at 2711.36. [If the lower oxide is a protoxide, the data give 128.6 for O = 16.] The uranous oxide was prepared from pitchblende by solution in aqua regia, precipitation of heavy metals with hydrogen sulphide, precipitation with ammonic hydrate, solution in ammonium carbonate to remove iron, reprecipitation, heating to redness, washing with chlorydric acid to remove impurities, and reduction in hydrogen. (*Poggend. Ann.*, *1*, 1824, 254.)

E. Peligot: *119.128* (O = 16).

In two experiments the amount of carbon in the acetate was found to be 11.27 and 11.3; mean 11.285. In one experiment the uranic oxide was determined at 67.3 per cent. [From these data the above value follows.] Peligot takes 120 or 750, C = 75. The preparation of the salt is not given. Peligot mentions the oxalate and gives analyses, but does not deduce an atomic weight from them. (*Annal. de Chim. et de Phys.*, (3,) *5*, 1842, 39.)

J. J. Ebelmen: *118.86* (O = 16); 742.875 (O = 100).

Ebelmen made six experiments on the reduction of the oxalate to uranous oxide by hydrogen and heat. The value follows with an extreme difference of 0.65 for C = 75; H = 12.5. All the weighings were reduced to vacuum. To obtain pure oxalate, the nitrate was precipitated by oxalic acid and this preparation decomposed by heat. The oxide thus obtained was digested with chlorhydric acid, washed, dissolved in nitric acid, recrystallized, and precipitated with oxalic acid. The oxalate was dried at 100°. According to Rammelsberg the reduction of the oxalate is accompanied by the separation of carbon which remains with the oxide. (*Annal. de Chim. et de Phys.*, (3,) *5*, 1842, 189.)

Berzelius, Arfvedson, Marchand: 128.4 (O = 16); 802.49 (O = 100).

While Arfvedson was making his first determination, Berzelius also made an experiment on the combustion of ura-

nous oxide getting 103.685 uranic from 100 uranous oxide. Marchand (*Erdmann's Journ. für Prak. Chem.*, *23*, 1841, 498) got in the same way 103.668. The average of the combustion experiments of all three chemists is 103.694, whence Berzelius calculates the value. (*Berzelius' Jahresbericht*, *22*, 1842, 113.) Peligot and Rammelsberg, as well as Marchand, point out faults in this method, such as the probable condensation of hydrogen in the protoxide and the tendency to form higher oxides. (*Poggend. Ann.*, *59*, 1843, 4.)

C. RAMMELSBERG.

This chemist made experiments on the reduction by hydrogen of the green oxide, prepared in various ways, and got results varying from 580.4 to 767.6 for O = 100. (*Poggend. Ann.*, *59*, 1843, 9.) By precipitation of uranous chloride with silver he reached the number 787.5 for Cl = 442.65. The chlorine contents found varies in three experiments from 73.89 to 74.46. The chloride was prepared by heating uranous oxide in an atmosphere of chlorine. (*Poggend. Ann.*, *55*, 1842, 321.)

J. WERTHEIM: *119.42* (O = 16); 746.36 (O = 100).

Determined by three experiments on the decomposition of the double acetate of uranium and sodium. The mean loss of acetic acid by heating the salt to redness was 32.477 per cent.; extreme difference, 0.036. The number follows for C = 75, H = 6.25, Na = 390.9. [In *Poggend. Ann.*, *57*, 484, an abstract is given of a paper read before the academy (of Berlin?) by Mitscherlich, in which he states that Wertheim's experiments above described give 740.512. Berzelius in his *Jahresbericht*, *23*, 137, makes or quotes the same statement, so also does Rammelsberg, *Poggend. Ann.*, *59*, 4, and it has been repeated elsewhere. I have recalculated the data given by Wertheim and find the results correctly deduced in his own report. For Na = 23.043 (Stas); the data give U = 119.53.] The salt was prepared from uraninite by solution in nitric acid, precipitation with hydrogen sulphide, evaporation of the filtrate to dryness, solution in hot water, crystallization and recrystallization, heating the crystals to drive off nitric acid, solution in acetic acid, digestion with sodium carbonate and recrystallization. (*Erdmann's Journ. für Prak. Chem.*, *29*, 1843, 209.)

C. RAMMELSBERG: about 120 (O = 16).

Determined in six experiments, undertaken at Berzelius' suggestion, by treating uranous oxide with nitric acid and sulphuric acid and weighing the sulphate. It is very difficult to weigh the uranous oxide which constantly increases in weight. Two experiments were made on the green oxide, which was prepared either by heating uranous oxide, or the nitrate, in air. Two experiments were made on magnesium uraniate by dissolving the compound in nitric acid and heating to redness. The compound was found unstable in character. One experiment was made by heating the double acetate of uranium and sodium and three experiments by heating the double acetate of barium and uranium. The results obtained varied from 633.17 to 753.76. Rammelsberg considers the determinations confirmatory of Wertheim's and Ebelmen's. (*Poggend. Ann.*, *66*, 1845, 95.)

E. PELIGOT: 120 (O = 16); 750 (O = 100).

Determined by combustion of the oxalate in a current of air, both the carbonic acid and the green oxide of uranium being weighed. At first Peligot got only 730 as the atomic weight by this process, but by repeating the recrystallization of the salt until determinations gave constant results, he got a mean of 750. He says that he came to the same value by comparing the amount of uranic oxide obtained from the acetate with the weight of the salt employed. (*Paris Comptes Rend.*, *22*, 1846, 487.)

VANADIUM.

Roscoe has determined the vapor density of vanadium chloride. It agrees with an atomic weight of about 51. (*L. Meyer*, *l. c.*)

J. J. BERZELIUS: *52.47* (O = 16).

Berzelius made four experiments on the relation between the higher and the lower oxides of vanadium, three by reduction with hydrogen at a very high temperature and one by oxidation. He supposed the higher oxide to have the formula VO_3, and the lower VO, and consequently got for

the atomic weight the number 855.84 (O = 100). R. Schneider has shown that the data as given by Berzelius are discordant, (*Poggend. Ann.*, *88*, 319,) a fact of small importance in view of the succeeding investigation. The higher oxide analyzed by Berzelius was produced by gently heating the ammonium salt. (*Poggend. Ann.*, *22*, 1831, 14; *Kongl. Vet. Akad. Handl.*, 1831.)

Roscoe examined some ammonium vanadate which Berzelius had sent Faraday and found that it contained phosphorus. (*Liebig's Ann.*, *S*, *6*, 1868, 93.)

H. E. Roscoe: 51.33 (O = 16).

Roscoe made four experiments on the reduction of vanadic acid ($V_2 O_5$) in carefully purified hydrogen. The acid was prepared from ammonium vanadate. To free this compound from phosphorus and silicic acid it was powdered, decrepitated with sodium in an iron crucible, washed with water and with chlorhydric acid, re-oxidized with nitric acid, chloridized in a current of chlorine, the chloride rectified and decomposed with water. The acid so obtained was dried, moistened with sulphuric acid, exposed to the fumes of fluohydric acid for ten days and melted. This pure acid was first heated for several hours in dry air and afterwards in hydrogen. The mean result of four experiments was V = 51.371; extreme difference, 0.228. Nine experiments were made on the titration of the chloride by Pelouze's method. Eight experiments were also made on the analysis of the chloride with argentic nitrate by the ordinary method. The mean of the seventeen experiments on the chloride gives the contents in chlorine at 61.276 per cent.; extreme difference, 0.69. This composition indicates an atomic weight of 51.29. Roscoe takes Cl = 35.457, Ag = 107.93. The vanadium chloride was purified by rectification over sodium in a current of carbon di-oxide. The reagents were prepared according to Stas. (*Liebig's Ann.*, *S*, *6*, 1868, 86.)

Roscoe mentions atomic weight determinations by Czudnowicz as giving 55.35. This chemist, however, did not calculate an atomic weight from his analyses, but used that obtained by Berzelius. (*Poggend. Ann.*, *120*, 1863, 17.)

YTTRIUM.

The composition of yttrium oxide is not definitely settled. Mendelejeff concludes from the general behavior of its compounds that it is a sesqui-oxide. As, however, all the chemists who have made atomic weight determinations of this element have considered it a prot-oxide, I shall assume it to be so and the atomic weight, therefore, about 60.

J. J. BERZELIUS: *64.29* (O = 16); 401.84 (O = 100).

This determination was made before the discovery of erbium and can scarcely be correct. The value was reached by analysis of the sulphate with barium chloride. Ba = 856.88, S = 201.165. (*Poggend. Ann.*, *8*, 1826, 186; *10*, 1827, 341.)

N. J. BERLIN: 59.7 (O = 16).

According to Blomstrand in *Berlin, Ber. der Chem. Ges.*, 1873, 1467. I can find no other record of this determination which probably appeared in the *Forhandl. ved de Skandinaviske Naturforsk*, 1860, 448.

O. POPP: 68 (O = 16),

The mean of four analyses of the sulphate showed that 40.15 oxide were equivalent to 38.23 sulphuric anhydride, giving a molecular weight for the oxide of 42.015; extreme difference, 0.013. The yttrium was precipitated with sublimed oxalic acid, the free acid being afterwards neutralized with ammonia. The sulphuric acid was precipitated with barium chloride in the filtrate with precautions. Popp, who denies the existence of erbium and terbium, separated yttrium from the cerite oxides by precipitation with barium carbonate, yttrium remaining in solution, S = 16, Ba = 68.5. (*Liebig's Ann.*, *131*, 1864, 183.)

M. DELAFONTAINE: about 64 (O = 16).

Delafontaine does not pretend that this number is exact. It is derived from analyses of the sulphate. His method of separation was essentially Mosander's, which was proved by Popp and by Bunsen and Bahr to give impure salts. (*Liebig's Ann.*, *134*, 1865, 108.)

BAHR AND BUNSEN: 61.7 (O = 16).

Determined by saturating the oxide with sulphuric acid as in the determination of erbium, *q. v.* Partial recrystallization does not produce pure yttrium nitrate, but only concentrates traces of didymium in the salt. Didymium must be separated with potassic sulphate. Erbium nitrate is more easily decomposed by heat than yttrium nitrate. The nitrates were therefore partially decomposed, yttrium nitrate dissolved out and the process repeated until there was no trace of erbium or didymium visible in the spectroscope. The mean of two determinations gave Y = 30.85; difference, 0.1. S = 16. (*Liebig's Ann.*, *137*, 1866, 21.)

M. DELAFONTAINE: 58.5 (O = 16).

Determined by three experiments on the sulphate which gave in mean 48.23 per cent. oxide for S = 32. [In the *Jahresbericht* this determination is reported as giving Y = 74.5. Yttrium is apparently a misprint for yttrium oxide.] The yttrium salt seems to have been prepared according to the method of Bahr and Bunsen. (*Kopp's Jahresbericht*, 1866, 184; *Bibl. Univ.*, *Arch. des Sciences*, (2), *25*, 1866, 112.)

P. T. CLEVE AND O. M. HOEGLUND: 59.7 (O = 16).

Determined by analysis of the sulphate. The oxide was purified by heating the nitrates, etc., according to N. J. Berlin. (Blomstrand, in *Berlin*, *Bericht der Chem. Ges.*, 1873, 1467; *Bihang till Vet. Akad. Handl*, 1873, B. 1, *3*, No. 8.)

ZINC.

The specific heat of zinc has been determined by Regnault and others. The vapor density of volatile organic compounds has been determined by Frankland and others. These experiments agree in placing the atomic weight at about 65. (*Gmelin-Kraut*, *l. c.*; *L. Meyer*, *l. c.*)

GAY-LUSSAC, BERZELIUS, WOLLASTON: *65.547* (O = 16); *409.67* (O = 100).

In his experiments on the oxidation of zinc Gay-Lussac

found that 100 Zn = 24.41 oxygen. This value is repeatedly cited in his memoir. (*Gilbert's Ann.*, *30*, 1811, 297; *Mémoire D'Arceuil*, *2*, 174.) Wollaston gives the same figures on Gay-Lussac's authority. (*Phil. Trans.*, *104*, 1814, 21.) Wollaston calculates from these data Zn = 410, (O = 100.) Berzelius in each of two experiments got 100 Zn = 124.4 oxide. (*Gilbert's Ann.*, *37*, 1811, 460.) In *Poggend. Ann.*, *8*, 1826, 184, as well as in his *Lehrbuch*, Berzelius cites Gay-Lussac as having found 100 Zn = 24.8 oxygen. He states that his own determinations were in perfect accordance with these figures, and calculates from them the atomic weight of zinc at 403.226 or *64.52*, and this was the accepted value for many years. I cannot find any other determinations by either of these chemists, and am obliged to suppose that there was a mistake made in recording the data from which Berzelius made his calculations; if so, it is remarkable that neither Berzelius nor the other chemists who determined this value perceived it; for the question was reopened during Berzelius' life, and A. Erdmann made his determination at Berzelius' request.

V. A. Jacquelin: *66.24* (O = 16); 414 (O = 100).

This number was reached by measuring the amount of hydrogen developed by a known weight of zinc from sulphuric acid on the supposition that the specific gravity of hydrogen is 0.0624. The results seem to have been inconsistent. Subsequently Jacquelain arrived at the same number by oxidizing an impure zinc of known composition. (*Paris Comptes Rend.*, *14*, 1842, 636; and *Annal. de Chim. et de Phys.*, (3,) *7*, 1843, 204.)

P. A. Favre: *66*, (O = 16); 412.5 (O = 100).

Favre made four experiments on the combustion of zinc oxalate, the carbon di-oxide being collected and its weight compared with that of the oxide. The mean result was Zn = 412.66; extreme difference, 1.11. C = 75. He also made three experiments by passing the hydrogen developed by a known weight of zinc over cupric oxide, the water being caught. These experiments gave in mean Zn = 412.16; extreme difference, 0.65 for H = 12.5. (*Annal. de Chim. et de Phys.*, (3), *10*, 1844, 163.)

A. Erdmann; *65.05* (O = 16); 406.591 (O = 100).

Determined by oxidizing pure zinc with nitric acid, and

driving off the acid by heating the salt in a porcelain crucible. Platinum is attacked. The number is the mean of four experiments; extreme difference, 0.698. The zinc was prepared by mixing pure oxide with carbon, and distilling in a current of hydrogen. (*Berzelius' Jahresbericht*, *24*, 1844, 132; *Œfversigt af Kongl. Vet. Akad. Handl.*, *1*, 3.)

ZIRCONIUM.

Deville and Troost have determined the vapor density of the chloride. It agrees with an atomic weight of about 90. (*L. Meyer*, *l. c.*)

J. J. Berzelius: *89.6* (O = 16).

In one experiment the sulphate was decomposed with ammonic hydrate, the oxide weighed and the sulphuric acid precipitated with barium chloride. In five experiments the sulphate was decomposed at a white heat, ammonium carbonate being added at the close of the operation. The mean result was that 100 parts of sulphuric anhydride unite with 75.853 parts of zirconium oxide; extreme difference, 0.23. Berzelius deduces the value 840.08 for O = 100, S = 201.165; on the supposition that the oxide contains three atoms of oxygen. [Being a binoxide, this relation gives Zr = 89.6 for O = 16.] The sulphate seems to have been prepared by dissolving the oxide in sulphuric acid and expelling the excess of acid by heat. (*Poggend. Ann.*, *4*, 1825, 126.)

R. Hermann:

This chemist made some experiments on the chloride getting in three determinations a mean of 839.45 for O = 100 and on the tri-oxide supposition. The extreme difference was 20.1. Cl = 443.65. The chloride was produced by heating the oxide with carbon in a current of chlorine. Hermann adopts not his own but Berzelius' determination. (*Erdmann's Journ. für Prak. Chem.*, *31*, 1844, 77.)

C. Marignac: 90 (O = 16).

Determined from analyses of potassium fluo-zirconiate. The salt was decomposed with sulphuric acid, the excess

of acid driven off by heat, the residue weighed, the potassic sulphate leached out with water, and the residue again weighed. Marignac does not pretend that the determination is accurate. The results gave from 45.01 to 45.48. He thinks that some potassic sulphate may have escaped solution, and therefore takes the minimum. K = 39, S = 16.

According to Marignac, Deville also found the atomic weight of zirconium somewhat higher than Berzelius by analysis of the chloride with which he determined the vapor density. (*Annal. de Chim. et de Phys.*, (3,) *60*, 1860, 257.)

APPENDIX.

DETERMINATIONS BY T. THOMSON.

In *Thomson's Annals of Philosophy*, volumes *16* and *17*, 1820-21, Thomson published a series of papers descriptive of experiments undertaken for the purpose of verifying Prout's hypothesis. His method consisted in mixing re-agents in what he considered equivalent proportions, and after precipitation examining portions of the supernatant liquid for an excess of each of the salts supposed to neutralize one another. In all except four cases, either the salt analyzed was a sulphate and the precipitant barium chloride, or the determination was dependent upon such an analysis; yet although Thomson took barium = 70, in no instance was he able to detect either barium or sulphuric acid in the residual solution when the quantity of the re-agents corresponded to the atomic weights which he adopts. Comparison of his results with those reached by more accurate experimenters will make this exact neutralization appear impossible, nor were his contemporaries able to repeat his experiments successfully. Thomson's determinations are, as such, utterly valueless, yet as they were for many years extensively accepted in English and American scientific literature they are inserted here for reference. In the following table Thomson's numbers are multiplied, when necessary, for the sake of comparison with the values now accepted.

DETERMINATIONS INVOLVING BARIUM = 70.

Arsenic	76	Magnesium	24
Barium	140	Manganese	56
Bismuth	216	Nickel	52
Calcium	40	Nitrogen	14
Carbon	12	Phosphorus	32
Chlorine	36	Potassium	40
Chromium	56	Silver	110
Cobalt	52	Sodium	24
Copper	64	Strontium	88
Iron	56	Sulphur	32
Lead	208	Zinc	68

THOMSON FURTHER DETERMINED—

Antimony at 132 by oxidation.
Boron at 12 from analysis of borax.
Mercury at 200 by conversion of the oxide into chloride.
Tin at 116 by oxidation with nitric acid.

REDUCTION OF WEIGHINGS TO VACUUM.

In discussing the analyses recorded in the foregoing pages, or in reconciling atomic weight determinations by various chemists, it may be found convenient to employ the following table. The maximum error involved is less than 0.01 per cent. or 0.1 milligram per gram.

GRAM WEIGHTS BEING OF BRASS, FRACTIONS OF PLATINUM.

For substances the sp. gr. of which exceeds 6.1; no correction is necessary.

For substances the sp. gr. of which is less than 6.1 :—

To correct the entire grams; multiply their number by the correction in the table opposite the sp. gr. of the substance, found in the *first* column, and add the product to the observed weight.

To correct the fractions of a gram, multiply the correction opposite the sp. gr. of the substance, found in the *third* column of the table, by the first two decimal figures of the observed weight, if the sp. gr. of the substance is *less* than 3, and by the first decimal only, if the sp. gr. exceeds 3, and add the product to the observed weight.

ALL WEIGHTS USED BEING OF PLATINUM.

For substances the sp. gr. of which exceeds 7.8, no correction is necessary.

For substances the sp. gr. of which is less than 7.8 :— Multiply the correction opposite the sp. gr. of the substance, found in the *third* column, by the number of grams, tenths and hundredths observed, if the sp. gr. falls short of 3, or by the number of grams and tenths, if the sp. gr. exceeds 3, and add the product to the observed weight.

The table shows within what limits it is necessary to know the sp. gr.

Weights of Brass) for ecific Gravity between—		*Correction per Gram Error* $< \frac{1}{50}$ *Mg.*	*(Weights of Platinum) for Specific Gravity between—*	
27.738 and	11.064	—0.000 067 gram		
11.064	6.904	0.000 000	51.766 and	13.568
6.904	5.019	+0.000 067	13.568	7.807
5.019	3.943	0.000 133	7.807	5.480
3 943	3.247	0 000 200	5.480	4.222
3.247	2.759	0.000 267	4.222	3.433
2.759	2 399	0 000 333	3.433	2.893
2.399	2.122	0.000 400	2.893	2.500
2.122	1.903	0.000 467	2.500	2.201
1.903	1.724	0 000 533	2.201	1.965
1.724	1.576	0.000 600	1.965	1.776
1.576	1.452	0.000 667	1.776	1.619
1.452	1 377	0.000 733	1.619	1.488
1.377	1.254	0 000 800	1.488	1.377
1.254	1.174	0.000 867	1.377	1.281
1 174	1.103	0.000 933	1.281	1.197
1.103	1.041	0.001 000	1.197	1.124
1.041	0.985	0.001 067	1.124	1.059
		0.001 133	1.059	1.002
		0.001 200	1.002	0.950

(*Sill. Amer. Jour.*, *16*, 1878, 265; *Liebig's Ann.*, *195*, 1879, 2.)

INDEX TO AUTHORITIES.

Acta Universitatis Lundensis, 90.

Afhandlingar i Fysik, etc., 79.

Annales de Chimie et de Physique, 8, 10, 12, 13, 15, 19, 20, 21, 22, 24, 28, 30, 35, 40, 41, 42, 43, 47, 50, 51, 55, 56, 61, 62, 63, 65, 66, 67, 71, 72, 73, 74, 77, 78, 79, 81, 84, 86, 87, 88, 93, 97, 100, 102, 104, 106, 109, 111, 113, 115, 118, 119, 123, 124, 126, 127, 129, 135, 137.

Berlin, Bericht der Deutschen Chemischen Gesellschaft, 18, 48, 49, 54, 59, 89, 105, 134.

Berzelius' Lehrbuch der Chemie, 7, 12, 14, 17, 18, 22, 23, 26, 27,28, 29, 38, 46, 49, 54, 56, 71, 74, 76, 80, 82, 83, 86, 98, 105, 112, 114, 116, 120, 121, 124.

Berzelius' Jahresbericht über die Fortschritte der Chemie, etc., 8, 41, 56, 62, 65, 66, 74, 78, 79, 80, 86, 92, 93, 100, 108, 114, 115, 125, 130, 136.

Bibliothèque Universelle de Genève, Archives des Sciences, 15, 16, 22, 27, 32, 41, 46, 47, 62, 72, 84, 87, 88, 91, 93, 100, 108, 113, 134.

Bihang till Vetenskaps Akademien Handlingar, 134. (See Kongliga Vetenskaps Akademien.)

British Association Reports, 15, 19.

Bulletin de la Société Chimique, 53, 54, 122.

Bulletin de l'Académie Royale des Sciences, etc., de Belgique, 32, 33.

Chemical News, 25, 48, 65, 89.

Edinburgh Royal Society Transactions, 56, 80.

Erdmann's Journal für Praktische Chemie, 18, 23, 24, 27, 28, 29, 31, 35, 37, 44, 45, 48, 49, 52, 55, 58, 59, 60, 62, 67, 68, 69, 76, 77, 78, 79, 81, 83, 86, 88, 90, 92, 94, 96, 102, 104, 114, 117, 119, 122, 126, 127, 130, 136.

Fresenius' Zeitschrift für Analytische Chemie, 48, 50, 52, 89.

Forhandlinger ved de Skandinaviske Naturforskeres, 133.

Gilbert's Annalen der Physik, etc., 96, 123, 135.

Gmelin-Kraut, Handbuch der Chemie, 7, 9, 12, 13, 18, 19, 20, 21, 23, 26, 37, 43, 46, 49, 56, 62, 64, 65, 68, 73, 76, 79, 81, 83, 86, 90, 91, 94, 95, 96, 98, 101, 102, 103, 106, 110, 111, 113, 117, 118, 122, 123, 125, 128, 134.

Halle, Zeitschrift für die Gesammten Naturwissenschaften, 45.

Jenaische Zeitschrift für Medicin und Naturwissenschaft, 52.

Journal de Pharmacie et de Chimie, 94.

Journal of the Chemical Society, 47, 88, 97.

Klatzo, Ueber die Constitution der Beryllerde, 18.

Kongliga Vetenskaps Akademien Handlingar, 21, 88, 94, 95, 101.

Kopp's Jahresbericht über die Fortschritte der Chemie, 45, 52, 53, 78, 104, 122, 134.

Laurent and Gerhardt's Comptes Rendus Mensuels, etc., 125.

Liebig's Annalen der Chemie, etc., 15, 26, 28, 29, 30, 31, 32, 35, 36, 37, 40, 41, 43, 51, 52, 53, 54, 68, 73, 75, 78, 86, 91, 93, 99, 103, 106, 107, 115, 116, 117, 120, 121, 125, 126, 128, 132, 133, 134.

Meyer, L., Moderne Theorien der Chemie, 7, 9, 12, 20, 28, 81, 113, 122.

Mitscherlich's Lehrbuch der Chemie, 30.

Œfversigt af Vetenskaps Akademien Fœrhandlingar, 79, 136. (See Kongliga Vetenskaps Akademien.)

Otto's German Translation of Graham's Chemistry, 33, 34, 67.

Paris Comptes Rendus, 8, 13, 15, 20, 26, 40, 42, 50, 55, 56, 58, 75, 83, 85, 89, 93, 95, 97, 100, 105, 111, 112, 116, 131, 135.

Pelouze, Traité de Chimie, 8.

Philosophical Magazine, 8, 17, 22, 30.

Philosophical Transactions of the Royal Society, 14, 26, 28, 33, 37, 38, 39, 43, 49, 54, 56, 65, 71, 72, 76, 82, 91, 92, 96, 99, 106, 107, 110, 112, 113, 114, 120.

Poggendorff's Annalen der Physik, etc., 9, 10, 11, 12, 13, 14, 17, 18, 19, 21, 24, 25, 26, 29, 33, 36, 38, 43, 45, 46, 49, 51, 53, 54, 59, 60, 61, 64, 65, 66, 67, 68, 91, 94, 95, 98, 99, 101, 102, 103, 104, 105, 106, 110, 114, 116, 118, 121, 122, 123, 124, 125, 127, 128, 129, 130, 131, 132, 133, 135, 136.

Proceedings of the American Academy of Arts and Sciences, 11, 12.

Schweigger's Journal für Chemie und Physik, 23, 86.

Scheikundige Verhandelingen en Onderzoekingen, 122.

Silliman's American Journal of Science, 25, 26, 37, 46, 74, 75.

Sitzungs-Bericht der k. k. Akademie zu Wien, 48, 81, 88, 97, 104, 118.

Stas, Untersuchungen über Chemischen Proportionen und Atomgewichte, 23, 43, 59, 62, 64, 73, 76, 94, 98, 101, 110, 111, 115.

Stockholm Akademien Handlingar, 18. (See Kongliga Vetenskaps Akademien.)

Thomson's System of Chemistry, 7, 14, 17, 20, 23, 24, 29, 61, 73.

Thomson's Annals of Philosophy, 58, 61, 139.

Thomson, R. D., Records of General Science, 92, 114.

Zeitschrift für Berg Hütten-und Salinen-Wesen im Preussichen Staate, 49, 51.

INDEX TO ATOMIC WEIGHT DETERMINATIONS.

ALLEN. (JOHNSON and)
Cæsium 25
Aluminium 7
ANDERSON, T.
Nitrogen 93
ANDREWS, T.
Barium 15
Platinum 98
Antimony 9, 140
ARAGO. (BIOT and)
Carbon 28
Nitrogen 91
ARFVEDSON, J. A.
Lithium 73
Manganese 79
Uranium 128, 129
Arsenic 12
AWDEJEW.
Beryllium 17

BAHR, J. F.
Magnesium 78
BAHR, J. F., and R. W. BUNSEN.
Erbium 53
Yttrium 134
BALARD, A. J.
Bromine 20
Barium 13
BERINGER, A.
Cerium 34
BERLIN, N. J.
Chromium 44
Molybdenum 84
Thorium 121
Yttrium 133
BERNOULLI, F. A.
Tungsten 127
BERTHIER, P.
Nickel 86
Beryllium 16
BERZELIUS, J. J.
Aluminium 7
Antimony 9
Arsenic 12
Barium 14
Beryllium 17
Boron 19
Bromine 21
Calcium 26, 28
Carbon 29

BERZELIUS, J. J.
Chlorine 37, 38
Chromium 43
Copper 49
Fluorine 54
Gold 56
Iodine 61
Iridium 64
Iron 65, 66
Lead 71
Lithium 74
Magnesium 76
Manganese 79, 80
Molybdenum 83
Nickel 87
Nitrogen 91
Osmium 94
Palladium 95
Phosphorus 96
Platinum 98
Potassium 99
Rhodium 101
Selenium 104
Silicon 105
Silver 106
Sodium 110
Sulphur 113, 114
Tantalium 116
Tellurium 118
Thorium 120
Tin 122
Tungsten 125
Uranium 129
Vanadium 131
Yttrium 133
Zinc 134
Zirconium 136

BERZELIUS and DULONG.
Hydrogen 57
Nitrogen 91
BERZELIUS and LIEBIG.
Carbon 31
BIOT and ARAGO.
Carbon 28
Nitrogen 91
Bismuth 18, 139
BLOMSTRAND, C. W.
Niobium 90
BOISBAUDRAN, L. DE
Gallium 56

BORCK, J. B. VON
Tungsten 126
Boron 19, 140
BRANDES, R.
Manganese 80
BRODIE, B. C.
Graphon 33
Phosphorus 97
Bromine 20
BUEHRIG, H.
Cerium 37
BUNSEN, R. W.
Cæsium 25
Indium 60
BUNSEN, R. W., and J. JEGEL.
Cerium 35
BUNSEN, R. W. (J. F. BAHR and)
Erbium 53
Yttrium 134
BUNSEN. (KIRCHOFF and)
Cæsium 24
Rubidium 102

Cadmium 23
Cæsium 24
Calcium 26, 139
CAPITAINE, H.
Iron 66
Carbon 28
Cerium 34
CHENEVIX, R.
Copper 49
Chlorine 37, 139
CHOUBINE.
Lanthanium 68
Chromium 43
CHYDENIUS, J. J.
Thorium 121
CLAUS, C. E.
Iridium 65
Ruthenium 103
CLEVE, P. T.
Didymium 53
Erbium 53
Lanthanium 70
Thorium 121
CLEVE, P. T., and O. M. HOEGLAND.
Erbium 54
Yttrium 134

Cobalt 46, 139
COMMAILLE. (MILLON and)
Copper 50
COOKE, J. P., Jr.
Antimony 11
Copper 49, 139
CROOKES, W.
Thallium 119, 120
CZUDNOWICZ, C.
Lanthanium 69

DAVY, H.
Fluorine 54
Mercury 82
Silver 106
DAVY, J.
Sodium 110
DEBRAY, H.
Molybdenum 84
DEBRAY. (DEVILLE and)
Osmium 94
DELAFONTAINE, M.
Erbium 53
Molybdenum 84
Thorium 121
Yttrium 133, 134
DEMOLY, A.
Titanium 124
DEVILLE, H. SAINTE-CLAIRE
Nickel 87
DEVILLE and DEBRAY.
Osmium 94
DEVILLE. (WOEHLER and)
Boron 19
DEXTER, W. P.
Antimony 10
Didymium 51
DIEHL, K.
Lithium 75
DULONG. (BERZELIUS and)
Hydrogen 57
Nitrogen 91
DUMAS, J.
Aluminium 8
Antimony 10
Arsenic 12, 13
Barium 16
Bismuth 19
Bromine 22
Cadmium 24
Calcium 26, 28
Carbon 29
Chlorine 42
Cobalt 47
Copper 50
Fluorine 55
Hydrogen 58
Iodine 61, 62
Iron 67
Lead 72

DUMAS, J.
Magnesium 79
Manganese 81
Molybdenum 84
Nickel 87
Nitrogen 93
Phosphorus 97
Potassium 100
Selenium 104
Silicon 105
Sodium 111
Strontium 113
Sulphur 115
Tellurium 118
Tin 122
Tungsten 126
DUMAS and STAS.
Carbon 30

EBELMEN, J. J.
Uranium 129
EINBRODT, P.
Nitrogen 93
EKMAN, G. (O. PETTERSSON and)
Selenium 105
Erbium 53
ERDMANN, A.
Zinc 135
ERDMANN and MARCHAND.
Calcium 27
Carbon 30
Copper 49
Hydrogen 58
Iron 66
Mercury 82
Nickel 86
Selenium 104
Sulphur 114
ERK, C.
Didymium 52
Lanthanium 70

FAVRE, P. A.
Zinc 135
Fluorine 54
FOURCROY and THENARD.
Mercury 82
FOWNES, G.
Carbon 30
FREMY, E.
Fluorine 55
Osmium 94
FREMY. (PELOUZE and)
Aluminium 8

Gallium 55
GAY-LUSSAC, L. J.
Iodine 61
Magnesium 76

GAY-LUSSAC, L. J.
Zinc 134
GERHARDT, C.
Chlorine 41
GIBBS, W.
Cerium 37
Cobalt 46
GMELIN, C. G.
Lithium 73
GMELIN-KRAUT.
Boron 19
Carbon 33
Iodine 62
GODEFFROY, R.
Cæsium 25
Rubidium 103
Gold 56
Graphon 33

HAGEN, R.
Lithium 74
HAMPE, W.
Copper 50
HAUER, K. VON
Cadmium 23
Manganese 80
Tellurium 118
HEBBERLING, M.
Thallium 119
HENRY, W.
Magnesium 76
HERMANN, R.
Cerium 34
Didymium 51
Lanthanium 68, 69
Lithium 73
Niobium 90
Tantalium 117
Zirconium 136
HILLEBRAND, W. F.
Didymium 53
HISINGER, W.
Cerium 34
HOEGLUND, O. M. (P. T. CLEVE and)
Erbium 54
Yttrium 134
HOLZMANN, M.
Lanthanium 68
Hydrogen 57

Indium 59
Iodine 61
Iridium 64
Iron 65, 139
ISNARD.
Aluminium 8

JACQUELAIN, V. A.
Chromium 44

JACQUELAIN, V. A.
Iodine 62
Magnesium 78
Phosphorus 97
Zinc 135
JEGEL, J. (R. BUNSEN and)
Cerium 35
JOHNSON and ALLEN.
Cæsium 25

KEMPE. (LEICHTE and)
Molybdenum 85
KESSLER, F.
Antimony 10
Arsenic 13
Chromium 45
KIRCHHOFF and BUNSEN.
Cæsium 24
Rubidium 102
KJERULF, T.
Cerium 35
KLAPROTH, M. H.
Potassium 99
Strontium 112
KLAPROTH. (WOLLASTON and)
Barium 13
KLATZO, G.
Beryllium 18
KRALOVANSZKY.
Lithium 73
KRAUT. (GMELIN—)
Boron 19
Carbon 33
Iodine 62

LAGERHJELM, P.
Bismuth 18
LAMY, A.
Thallium 118
Lanthanium 67
LASSAIGNE.
Nickel 86
LAURENT, A.
Boron 20
Chlorine 40, 42
Lead 70, 139
LEE, R. H.
Cobalt 48
Nickel 89
LEFORT, J.
Chromium 45
LEICHTE and KEMPE.
Molybdenum 85
LENSSEN, E.
Cadmium 24
LEVOL, A.
Gold 56
Potassium 100

LIEBIG, J.
Bromine 21
LIEBIG and REDTENBACHER.
Carbon 31
Silver 108
LIEBIG. (BERZELIUS and)
Carbon 31
Lithium 73
LOEWIG, C.
Bromine 21
LONGCHAMP.
Magnesium 76
LOUYET, P.
Fluorine 55
LUCCA, S. DE
Fluorine 55

MACDONNELL, A.
Magnesium 78
Magnesium 76, 139
MAGNUS, G.
Iron 65
MALLET, J. W.
Lithium 74
Manganese 79, 139
MARCET.
Chlorine 37
Silver 106
MARCHAND, R. F.
Tungsten 126
Uranium 129
MARCHAND and SCHEERER.
Magnesium 76
MARCHAND. (ERDMANN and)
Calcium 27
Carbon 30
Copper 49
Hydrogen 58
Iron 66
Mercury 82
Nickel 86
Selenium 104
Sulphur 114
MARIGNAC, C.
Barium 15, 16
Bromine 21
Calcium 27
Carbon 32
Cerium 35
Chlorine 39, 40
Cobalt 46
Didymium 51
Iodine 62
Lanthanium 68
Lead 72
Nickel 87
Niobium 90
Nitrogen 92
Potassium 99, 100

MARIGNAC, C.
Silver 107, 108
Strontium 112
Tantalium 117
Zirconium 136
MATHER, W. W.
Aluminium 7
MAUMENÉ, E. J.
Chlorine 41
Iron 67
Potassium 100
Silver 108
MENDELEJEFF, D.
Cerium 37
Didymium 52
Erbium 53
Lanthanium 70
Uranium 128
MERCER.
Cæsium 25
Mercury 81, 140
MEYER, L.
Molybdenum 85
Uranium 128
MILLON, E.
Iodine 62
Mercury 83
MILLON and COMMAILLE.
Copper 50
MITSCHERLICH, E.
Carbon 30
MOBERG, A.
Chromium 44
Molybdenum 83
MOSANDER, C. G.
Lanthanium 68
Titanium 124
MULDER, G. J.
Tin 122

Nickel 86, 139
Niobium 89
Nitrogen 91
NORDENFELDT. (SVANBERG and)
Magnesium 77
NORLIN. (SVANBERG and)
Iron 66

ODLING, W.
Aluminium 8
Osmium 94
OTTO, F. J.
Cerium 34
Lanthanium 67
Oxygen 95

Palladium 95
PELIGOT, E.
Chromium 44

PELIGOT, E.
Uranium ... 129, 131
PELOUZE, J.
Arsenic ... 12
Barium ... 15
Chlorine ... 40
Nitrogen ... 93
Phosphorus ... 96
Potassium ... 100
Silicon ... 105
Sodium ... 110
Strontium ... 112
PELOUZE and FREMY.
Aluminium ... 8
PENNY, F.
Chlorine ... 39
Nitrogen ... 92
Potassium ... 99
Silver ... 107
Sodium ... 110
PETTERSSON, O., and G. EKMAN.
Selenium ... 105
PHILLIPS, R.
Chlorine ... 39
Phosphorus ... 96, 139
PICCARD, J.
Rubidium ... 102
PIERRE, J.
Titanium ... 124
Platinum ... 98
POPP, O.
Yttrium ... 133
Potassium ... 98, 139
PROUT, W.
Iodine ... 61

RAMMELSBERG, C.
Cerium ... 35, 36
Lanthanium ... 68
Niobium ... 90
Uranium ... 130, 131
RAWACK.
Manganese ... 81
REDTENBACHER. (LIEBIG and)
Carbon ... 31
Silver ... 108
REGNAULT.
Hydrogen ... 57
Nitrogen ... 91
REICH, F., and T. RICHTER.
Indium ... 59
RICHE, A.
Tungsten ... 126
RICHTER, T. (F. REICH and)
Indium ... 59
RIVOT, L. E.
Iron ... 67
Rhodium ... 101

ROSCOE, H. E.
Tungsten ... 128
Vanadium ... 132
ROSE, H.
Niobium ... 89, 90
Tantalium ... 116
Titanium ... 123
ROSE, H., and WEBER.
Antimony ... 9
ROSE, V.
Phosphorus ... 96
Strontium ... 112
ROTHOFF, E.
Cobalt ... 46
Nickel ... 86
Rubidium ... 102
RUSSELL, W. J.
Cobalt ... 47, 48
Nickel ... 88, 89
Ruthenium ... 103

SACC, F.
Selenium ... 104
SALVETAT.
Barium ... 15
Calcium ... 26
Strontium ... 112
SCHEERER, T.
Magnesium ... 77, 78
SCHEERER, T. (MARCHAND and)
Magnesium ... 76, 77
SCHEIBLER, C.
Tungsten ... 127
SCHIEL, J.
Silicon ... 106
SCHNEIDER, R.
Antimony ... 9
Bismuth ... 19
Cobalt ... 46
Manganese ... 81
Nickel ... 87, 88
Tungsten ... 125
SCHROETTER, A.
Phosphorus ... 97
Selenium ... 104
SEFSTROEM, N. G.
Mercury ... 82
Selenium ... 103
SIEWART, M.
Chromium ... 45
Silicon ... 105
Silver ... 106, 139
Sodium ... 111, 139
SOMMARUGA, E. VON.
Cobalt ... 47
Nickel ... 88
STAS, J. S.
Bromine ... 22
Carbon ... 32, 33

STAS, J. S.
Chlorine ... 42
Hydrogen ... 59
Iodine ... 63
Lead ... 72
Lithium ... 75
Nitrogen ... 93
Potassium ... 100
Silver ... 109
Sodium ... 111
Sulphur ... 115
STAS, J. S. (J. DUMAS and)
Carbon ... 30
STRECKER, A.
Carbon ... 32
Silver ... 108
STROMEYER, F.
Cadmium ... 23
Iron ... 65
Lithium ... 73
Strontium ... 112
Strontium ... 111, 139
STRUVE, H.
Barium ... 15
Sulphur ... 115
STRUVE, H., (L. SVANBERG and)
Molybdenum ... 83
Sulphur ... 113, 139
SVANBERG, L.
Mercury ... 83
Nitrogen ... 92
SVANBERG and NORDENFELDT.
Magnesium ... 77
SVANBERG and NORLIN.
Iron ... 66
SVANBERG and STRUVE.
Molybdenum ... 83

Tantalium ... 116
Tellurium ... 117
THALÉN.
Lanthanium ... 70
Thallium ... 118
THENARD, L. J., and F. H. WOLLASTON.
Iron ... 65
THENARD L. J., (FOURCROY and)
Mercury ... 82
THOMSEN, J.
Hydrogen ... 59
THOMSON, T.
Aluminium ... 7
Antimony ... 140
Arsenic ... 139
Barium ... 14, 139
Beryllium ... 17
Bismuth ... 139

THOMSON, T.
Boron 20, 140
Cadmium 23
Calcium 139
Carbon 29, 139
Cerium 34
Chlorine 139
Chromium 43, 139
Cobalt 139
Copper 139
Gold 56
Hydrogen 58
Iodine 61
Iron 139
Lead 139
Lithium 73
Magnesium 139
Manganese 139
Mercury 140
Nickel 139
Nitrogen 91, 139
Phosphorus 139
Potassium 139
Silver 139
Sodium 139
Strontium 139
Sulphur 114
Tin 140
Zinc 139
Thorium 120
Tin 122, 140
TISSIER, C.
Aluminium 8
Titanium 123
TROOST, L.
Lithium 74, 75
Tungsten 125
TURNER, E.
Barium 14
Chlorine 38
Lead 71
Manganese 80
Mercury 82
TURNER, E.
Nitrogen 91
Silver 106
Sulphur 114
UNGER, B.
Antimony 11
Uranium 128
Vanadium 131
VAUQUELAIN, L. N.
Lithium 73
VLAANDEREN, C. L.
Tin 122
WACKENRODER, H.
Iron 66
WALLACE, W.
Bromine 22
WATTS, W. M.
Iridium 65
Osmium 94
WEBER. (H. ROSE and)
Antimony 9
WEEREN, J.
Beryllium 17
WELESKY, P.
Cobalt 48
WENZEL.
Silver 106
WERTHEIM, J.
Uranium 130
WERTHER, H.
Thallium 119
WILDENSTEIN, R.
Chromium 45
WING, C. H.
Cerium 36
WINKLER, C.
Cobalt 48
Indium 60
Nickel 88
WOEHLER and DEVILLE.
Boron 19
Graphon 33
WOLF, C.
Cerium 36
WOLLASTON, F. H.
Calcium 26
Carbon 28
Chlorine 37
Copper 49
Hydrogen 57
Magnesium 76
Mercury 82
Nitrogen 91
Phosphorus 96
Potassium 99
Silver 106
Sodium 110
Strontium 112
Sulphur 113
Zinc 134
WOLLASTON and KLAPROTH.
Barium 13
WOLLASTON. (BERZELIUS and)
Lead 71
WOLLASTON. (L. J. THENARD and)
Iron 65
WREDE, F. VON
Carbon 32
Yttrium 133
ZETTNOW, E.
Tungsten 127
Zinc 134, 139
Zirconium 136
ZSCHIESCHE, H.
Didymium 52
Lanthanium 69

OCT 13 1928